JOURNAL

OF THE

AMERICAN SOCIETY OF NAVAL ENGINEERS

VOL. XXVII. AUGUST, 1915. No. 3.

The Society as a body is not responsible for statements made by individual members.

COUNCIL OF THE SOCIETY
(Under whose supervision this number is published).

Captain S. S. ROBISON, U. S. N. Captain B. C. BRYAN, U. S. N.
Eng.-in-Chief C. A. MCALLISTER, U.S.C.G. Lieut. Commander J. O. RICHARDSON, U. S. N.
Lieutenant A. T. CHURCH, U. S. N.

HEAT LOSSES IN STEAM TRANSMISSION.

BY W. L. CATHCART, MEMBER.

The action during the cooling of saturated steam is complex. Unless the steam velocity is high, a film of condensate adheres to the inner surface of the pipe. This film and that surface are usually assumed to be at the temperature corresponding with the pressure in the pipe, owing to the heat radiated from the column of steam. The film, however, acts also as an insulator to heat conduction from the steam, since the conductivity of water is, according to Lord Rayleigh, but $\frac{1}{115}$ that of iron. Further, between film and pipe, pipe and covering, and the covering and the surrounding air, external conduction takes place, meeting resistance at these three pairs of contact surfaces.

These various increments of resistance to heat transmission are shown roughly in Fig. 1. Let *Aa* be this resistance at the middle of an uncovered steam column, from which heat is dissipated chiefly by radiation but partially by conduction. Then, *Bb*, will be the resistance at the interface with the film. The low conductivity of the film increases the resistance to *Cc*, external conduction to the pipe adds the increment *cd*, internal conduction through the pipe metal makes the aggregate resistance *Ee*, external conduction to the covering

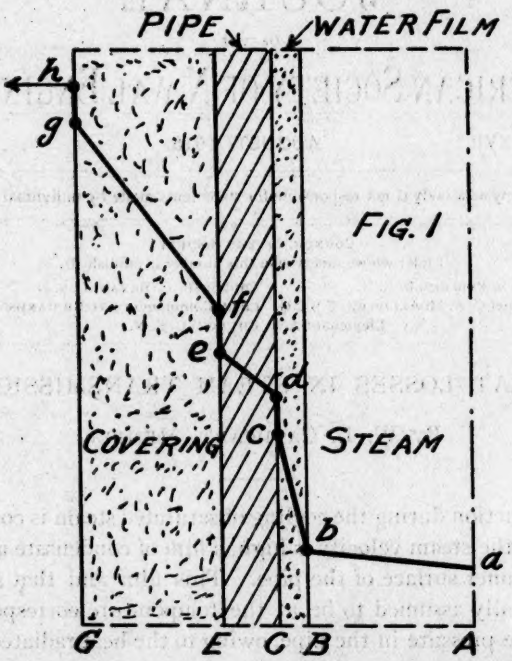


FIG. 1

increases the resistance by the amount *ef*, the passage of the covering raises the total to *Gg*, and external conduction to the surrounding air gives the final increment *gh*. The total resistance to heat transference from the middle of the column is then represented by *Gh*.

I. RADIATION AND CONDUCTION.

Heat is transmitted from one body to another by conduction, radiation, or both. The fundamental difference between these two processes is that the former proceeds by the direct agency of matter—the contact or other action of one molecule upon another—while, in radiation, there is no connecting medium perceptible to the senses between a hot radiating body and the cooler ones which absorb its heat.

The Stefan-Boltzmann law of radiation is: the radiation

of a black body is proportional to the fourth power of its absolute temperature, *i. e.*, if T be the absolute temperature of such a body, and T_0 that of another body to which radiation takes place, then, since radiation is a mutual action, the total energy radiated by the former body will be:

$$R = K(T^4 - T^4_0),$$

in which R, T, and T_0 may be expressed in any system of units and the value of the constant K depends on that system. This law was based on experiments by Stefan and later proved theoretically by Boltzmann. It has received ample experimental support. The difficulty in its practical use lies in giving K a proper value and in finding the temperature of the surface of the radiating body.

The principal factors governing radiated energy are:

(*a.*) *The Temperature Difference.*—As Stefan's law indicates, the higher relatively the absolute temperature of a radiating body, the greater proportionately will be the amount of energy radiated. With increasing temperature, the radiating power of all bodies tends to follow Stefan's law more closely.

(*b.*) *Condition of Radiating Surface.* — For surfaces of various characters, this condition is met by suitable values of the constants in the formulas. C. L. Norton* gives a practical example of the effect of pipe-surface on heat-loss during steam transmission. Stating the total heat-loss in B.t.u. per square foot of pipe-surface per minute, he found:

Condition of pipe-surface.	Heat-Loss.
New pipe,	11.96
Fair condition,	13.84
Rusty and black,	14.20
Cleaned with caustic potash, inside and out,	13.85
Painted dull white,	14.30
glossy white,	12.02
Cleaned with potash again,	13.84
Coated with cylinder oil,	13.90
Painted dull black,	14.40
glossy black,	12.10

* "Trans. Am. Soc. Mech. Engs.," Vol. XIX.

As conduction does not depend on the nature of the surface, the differences between these various total losses are due solely to changes in the amount radiated owing to the altered surface of the pipe. The temperature was that corresponding to 200 pounds pressure.

Internal Conduction. — Consider one surface of a metal plate of uniform thickness as maintained at the constant temperature t_1 and the other at the constant and lower temperature t_2. Let x be the thickness and A the area. Then, in the time T, the quantity of heat transmitted through the plate will be:

$$H = k\frac{(t_1 - t_2)\,AT}{x} \text{ and } k = \frac{Hx}{AT(t_1 - t_2)} \quad . \quad . \quad (1)$$

in which the constant k is the mean *internal conductivity* of the metal between the given temperatures. The reciprocal $\frac{1}{k} = r$ is the *internal thermal resistance.* These constants are coefficients whose absolute value depends on the system of units from which they were derived. They also vary with temperature.

The absolute conductivity of wrought iron, as deduced from the experiments of Forbes*, is 480.78 B.t.u. per hour, per square foot of plate one inch thick, per degree F. temperature-difference between the receiving and emitting surfaces.

Jaeger and Diesselhorst†, for the same system of units, obtained for wrought iron conductivities of 430.18 at 64.4 degrees F., and 406.77 at 212 degrees F. These values show, like the experiments of Forbes, the decrease in the conductivity of iron with increase in temperature.

Let $t_1 - t_2 = t$. Then:

$$t = \frac{Hx}{ATk} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (2)$$

which is practically an inconsiderable amount. Thus, in tests of a bare wrought-iron pipe, 0.2-inch thick with sat-

* Preston: Theory of Heat, London, 1904, p. 644.
† Sitzungsber. d. Berlin Akad., 1899, II, p. 746.

urated steam, it was found that 687 B.t.u. were lost per square foot per hour at a steam pressure of 81 pounds, gage. Taking k as 480, $t = 0.29$ degrees F. Again, the absolute internal thermal resistance of this pipe is $\frac{0.2}{480} = 0.00042$, which is negligible in practice.

Stefan found the conductivity of air to be 20,000 times less than that of copper, the latter being about 6.2 times that of iron. Superheated steam gives evidence of low internal conductivity. Thus, it has been found to exist unchanged in the same space, for a considerable period, with saturated steam and the water of condensation. Again, for efficient superheating, the tubes should be small, or, if large, should be fitted either with cores to form a thin annulus of steam or with deflecting plates to rotate the steam and throw the heavier and colder particles against the hot tube.

The conductivity of a pipe-covering may be materially reduced by giving it a cellular structure, providing the air-spaces are sufficiently small to minimize convection. In these conditions, air-spaces act in two ways: they increase the conductivity by giving opportunity for heat transmission by radiation, and decrease it through the low conductivity of the contained air, the net effect of the two actions being a reduction. Asbestos is *per se* a relatively good conductor; its cellular structure is what gives it efficiency as a covering.

External Conduction.—There is resistance to the flow of heat to or from any substance at its interface or joint with the emitting or receiving substance. This condition applies also to two parts of the same substance. If a rod be made of the same metal throughout, but in sections united by shrinkage fits or screw threads, there will be thermal resistance at every joint, and a solid rod of the same metal and dimensions will permit a freer flow of heat. A fusible plug melts at a lower temperature than that of the plate in which it is driven, owing to the interface resistance of the two metals.

As has been shown previously, the internal thermal resistance of a steam pipe is negligible, since the metal is capable

of conducting more heat than it can absorb or emit. The reverse is the case with pipe coverings. Their primary characteristic is low internal conductivity, and hence they can receive and deliver more heat than it is possible for them to conduct.

External conduction to or from a solid or fluid is a combination of two actions: emission by the heat-deliverer and absorption by the heat-receiver. The process is too complex for analysis. The general conditions governing it are: the temperature of the heat-delivering substance, the temperature-difference between heat-deliverer and heat-receiver, the state of rest or motion of both, the relative direction of these motions (contra-flow principle), and the character of the surfaces of the solid. In any case, the external conductivity at an interface is the reciprocal of the external thermal resistance there, and *vice versa.*

The formulae given below follow the general method of Mollier, the transfer of heat from one fluid to another through an intervening solid being divided into three stages: the external conduction from the first fluid (steam) to the solid (pipe metal), internal conduction through the latter, and external conduction from the pipe to the second fluid (air).

Let:

A = area of plate through which heat passes.
x = thickness of plate.
T = time during which heat is transmitted.
H = quantity transmitted during time T.
t_1 = temperature of steam.
t_2 = temperature of heat-receiving surface of plate.
t_3 = temperature of heat-delivering surface of plate.
t_4 = temperature of air.
k = coefficient of internal conductivity of plate.
k_1 = coefficient of external conductivity steam to plate.
k_2 = coefficient of external conductivity plate of air.
k_3 = coefficient of heat transmission, steam to air.

Since, during each of the three stages, the amount of heat transmitted is the same:

$$H = k_1 (t_1 - t_2) AT \quad . \quad . \quad . \quad . \quad . \quad . \quad (3)$$

$$H = \frac{k}{x} (t_2 - t_3) AT \quad . \quad . \quad . \quad . \quad . \quad . \quad (4)$$

$$H = k_2 (t_3 - t_4) AT \quad . \quad . \quad . \quad . \quad . \quad . \quad (5)$$

Combining and eliminating:

$$H = \frac{1}{\frac{1}{k_1} + \frac{x}{k} + \frac{1}{k_2}} \quad . \quad (t_1 - t_4) AT \quad . \quad . \quad . \quad (6)$$

$$H = \frac{1}{r_1 + xr + r_2} \quad . \quad (t_1 - t_4) AT \quad . \quad . \quad . \quad (7)$$

in which r represents thermal resistance. The fraction in (7) is the reciprocal of the sum of all the resistances met by the heat in passing from steam to air, and is therefore the coefficient of heat transmission, or

$$K_3 = \frac{1}{\frac{1}{k_1} + \frac{x}{k} + \frac{1}{k_2}} = \frac{1}{r_1 + xr + r_2} \quad . \quad . \quad . \quad . \quad (8)$$

The coefficients of external conductivity can be computed by these formulae, if the temperature of the outer surface of the pipe is known. It is impossible by ordinary methods to ascertain this temperature with scientific accuracy. As an example, take a test by Eberle * of superheated steam. The pipe was of wrought iron, 0.2 inch thick, uncovered, and the temperature of its outer surface was measured by thermo-elements. The data are:

Steam pressure, pounds per square inch, absolute	93.9
Steam temperature, degrees F	$555.8 = t_1$
Temperature of outer surface of pipe	$492.8 = t_3$
Temperature of air	$51.8 = t_4$
B.t.u. lost per square foot of outer surface per hour	$1{,}911.4 = H$
Steam velocity, feet per minute	5,905.8

* "Zeits. d. Ver. deuts. Ing.," April 16, 1908.

Taking $t_2 = t_3$ and A and T = unity, we have from (3) and (5), $k_1 = 30.3$ and $k_2 = 4.33$.

There is a marked difference between the values of k_1 for superheated and saturated steams, as deduced from these formulae. Saturated steam cannot lose heat without partial condensation, and hence there is not only a film of condensate adhering to the interior surface of the pipe, as shown in Fig. 1, but probably the column of moving steam has also a thin casing of condensate. Formulae (3) to (8) inclusive do not consider these insulating films, since the heat transfer through them is too complex a process. With highly superheated steam, these conditions do not prevail, since the pipe, if properly protected, is hotter than the corresponding temperature of saturated steam.

Rapid relative movement of the heat-delivering and heat-receiving surfaces increases the rate of heat-transfer, because this movement keeps the temperature-difference at its maximum. This is the principle which has been applied so successfully in the water-tube boiler and whose effects are marked also in the transmission of superheated steam. With saturated steam, however, despite the scrubbing action of moving steam, the films of condensate seem to linger at moderate velocities and to nullify the tendency toward increased heat-transfer from greater velocity. For example, Eberle's series of tests of superheated steam, cited previously, give the following average data:

Number of tests	9	7
Steam pressure, pounds per square inch, absolute	95 86	95.72
temperature, degrees F	456.0	578.7
velocity, feet per minute	1,870.7	5,905.8
Air temperature, degrees F	51.8	51.8
Heat-loss per hour per square foot of outer surface of pipe, B.t.u.	1,370.6	2,042.2

i.e., at the same pressure, although at a higher temperature, and at a steam velocity 3.16 times greater, there was an increase in the heat-loss per square foot of 49 per cent.

On the other hand, Gutermuth* gives a table comparing

*"Zeits. d. Ver. deuts. Ing.," 1887, p. 699.

the amount of condensate of saturated steam, when the latter was stationary and when it was flowing at various velocities. The following data are taken from this table.

Duration of test, hours.	Steam press., lbs., abs.	Steam velocity, ft. per min.	Condensate per hour (lb.) with steam.		Reduction in condensate due to steam velocity, per cent.
			Flowing.	Stationary.	
8.0	71.1	1,791	398.2	398.2	0.0
4.5	69.4	3,090	352.0	374.0	5.9
6.0	53.3	4,054	202.4	215.6	6.1
9.0	71.8	9,505	129.8	233.2	44.3

All of the 17 tests, except the first at low velocity as given above, showed reduced condensate with increased velocity. These results have been confirmed by recent tests of other investigators. It is, of course, possible that, with growing velocity, more of the condensate is entrained by the steam.

II. PÉCLET'S FORMULAE FOR HEAT LOSSES.

Péclet, who modified and extended the investigation of Dulong and Petit, established formulae for the radiation and conduction-losses of a cooling body which represent, in fair approximation, the actual results, and which, with a suitable correction, can therefore be used in practice.

The need of this correction arises from the fact that the investigations of these physicists, although most elaborate, were conducted within restricted limits of temperature and with special apparatus of small size, so constructed that all conditions could be regulated with certainty. Further, the cooling bodies employed by Péclet were metallic vessels filled with hot water, the coefficient of emissivity of which differs somewhat from that of steam. On the other hand, Russner found that results obtained by the use of the radiation factor determined by Péclet compared favorably with those from Stefan's law, Stefan himself showed that there was a reasonable agreement between his law and Dulong and Petit's formula

on which that of Péclet is based, and Pasquay, a pioneer in the invention and use of pipe-coverings, regards Péclet's formulae as satisfactory bases for computing the minimum loss in any given case. With regard to this, he says:*

"The values which we obtain from Péclet's formulae for the heat-losses of bare pipes are less than those found in practice, but these formulae were based on rigidly exact laboratory tests and assume still air, a condition which does not exist ordinarily even in enclosed spaces, still less in power plants or in mill rooms where there is movement of men and machinery or in passages or tunnels where the temperature-difference always causes a certain motion of the air, the intensity of which cannot be determined accurately. * * * It is important, however, to have formulae which (like Péclet's), will give us the minimum loss under the most favorable conditions."

Péclet limited his tests to those on bodies cooling in air at atmospheric pressure in an air-tight chamber with dull walls. As cooling bodies, he employed rectangular and spherical vessels of thin brass, filled with hot water kept continuously agitated. The rate of cooling, at a constant temperature of the air in the chamber, was found for the vessel when bare and when covered with various substances. The temperature-difference between cooling body and air, ranged from 45 degrees to 117 degrees F., with an average air temperature of 53.6 degrees. Within these limits, his results were in entire accord with the formulae of Dulong and Petit, and hence he decided that their formulae were exact up to the limit of temperature-difference, 468 degrees F., used by them. The important results of his experiments were the determination of the value of the coefficients for use in practice. As the formulae are empirical, the range fixed by Péclet should not be exceeded.

Heat Loss by Radiation.—Péclet's conclusions as to radiation were:

"The quantity of heat, per unit of surface and of time,

*"Warmeschutz im Dampfbetrieb:" Wasselnheim, 1900, p. 7.

emitted by radiation is independent of the size and form of the body—if the surface has no reëntrant portions (since radiation is a mutual action). This quantity depends only on the nature of the surface, on the excess of its temperature above that of the surrounding objects, and on the absolute value of the temperature of the latter."

His formula* is:

$$R = 124.72\ K\ a^{\theta}\ (a^{t} - 1) \quad . \quad . \quad . \quad . \quad . \quad (9)$$

in which, R is the quantity of heat in calories (large) emitted by radiation per square meter of surface per hour, t is the temperature-difference between this surface and the surroundings, θ is the temperature of the latter, *i.e.*, usually that of the air, a is a constant having for metric units the value 1.0077, and K, the radiation factor, is a number whose magnitude depends on the nature of the radiating surface. The temperatures are in degrees C.

This formula is too complex for ready computation, and hence Péclet tabulated the numerical values of the products of all the factors except K in the right-hand member of (9), for an air temperature of 15 degrees C. and temperature differences between 10 degrees and 250 degrees. The coefficients of K thus found have been reduced to British units and are given in Table 1. Below each coefficient is set the amount per degree F. of temperature difference to be added to that coefficient through the range between it and the next; at the foot are placed the factors by which the tabulated coefficients are to be multiplied for other coefficients.

The values of K, as determined by Péclet, are given in Table 2. The figures for paper and cloth apply to all colors.

From Table 1 and formula (9), it will be seen that the radiating power of a body increases slowly with the temperature of the surroundings and rapidly with the temperature-difference. Table 2 shows the marked advantage for preventing radiation, of a polished casing, especially as the greater part of the heat loss is due to this cause.

* "Traité de la Chaleur," Paris, 1860, I., p. 373.

TABLE 1.—HEAT LOSS BY RADIATION.

(Values of R in B.t.u. per square foot per hour of radiating surface per hour at an air temperature of 59 degrees F.)

Excess (t^0) of temperature of radiating surface above air temperature.	$R = K \times$	Excess (t^0) of temperature of radiating surface above air temperature.	$R = K \times$
Degrees F.		*Degrees F.*	
18	20.16	252	451.1
	1.2		3.26
36	41.76	270	543.78
	1.289		3.694
54	64.96	288	610.27
	1.403		3.836
72	90.22	306	679.32
	1.518		4.11
90	117.54	324	753.3
	1.642		4.472
108	147.1	342	833.8
	1.761		4.798
126	178.79	360	920.16
	1.915		5.181
144	213.26	378	1,013.42
	2.021		5.607
162	249.64	396	1,114.34
	2.261		6.034
180	290.34	414	1,222.96
	2.405		6.53
198	333.63	432	1,340.5
	2.597		10.403
216	380.38	450	1,527.75
	2.801		
234	430.79		
	3.017		

For air-temperature of....	32°	50°	68°	86°	104°	122°	140°	158°	176°	194°	212°
Multiply above values by	.89	.96	1.04	1.12	1.21	1.31	1.41	1.52	1.65	1.78	1.92

TABLE 2.—VALUES OF RADIATION FACTOR K.

(B.t.u. per square foot per hour per 1 degree F. of temperature difference.)

Silver, polished	.027	Powdered charcoal	.701
Copper	.033	Plaster	.738
Tin	.044	Wood	.738
Zinc, polished	.049	Cotton cloth (canvas)	.749
Brass	.053	Woolen cloth	.754
Sheet lead	.133	Silk	.761
Sheet iron, polished	.092	Oil paint	.761
Sheet iron, ordinary	.568	Paper	.773
Sheet iron, rusted	.689	Lamp-black	.822
Cast iron, new	.65	Water	1.089
Cast iron, rusted	.689	Oil	1.484

Heat Loss by Conduction.—Péclet's conclusions as to heat transmission by conduction to the air are:

"The loss of heat which is due to the contact of the air is independent of the nature of the surface of the body and of the temperature of the surrounding air. It depends only on the excess of the temperature of the body above that of the air and upon the form and dimensions of the body."

His formula for this loss is:

$$A = 0.552\ K'\ t^{1.233} \quad . \quad . \quad . \quad . \quad . \quad (10)$$

in which, A is the quantity of heat in calories (large) thus transmitted per square meter of surface per hour, t is the temperature difference between the surface and the surround-

TABLE 3.—HEAT LOSS BY CONDUCTION TO THE AIR.

Values of A in B.t.u. per sq. ft. of conducting surface per hour.

Excess ($t°$) of temperature of the surface above air-temperature.	$A = K' \times$	Excess ($t°$) of temperature of the surface above air-temperature.	$A = K' \times$
Degrees F.		*Degrees F.*	
18	16.92	252	439.99
	1.28		2.166
36	39.96	270	478.98
	1.44		2.206
54	65.88	288	518.69
	1.56		2.226
72	93.96	306	558.76
	1.64		2.276
90	123.48	324	599.72
	1.738		2.288
108	154.76	342	640.91
	1.804		2.334
126	187.24	360	682.92
	1.854		2.359
144	220.61	378	725.38
	2.09		2.381
162	258.23	396	768.24
	1.804		2.4
180	290.7	414	811.44
	2.		2.416
198	326.7	432	854.93
	2.058		2.354
216	363.74	450	897.3
	2.1		
234	401.54		
	2.136		

ing air, and K' is a number whose magnitude varies with the form and dimensions of the body.

Péclet computed from (10) the products of all factors except K' in the right-hand member, for temperature-differences as in Table 1. The coefficients thus found, reduced to British units, are given in Table 3 with also the differences per degree F.

The value of the conduction-factor K' depends on both the form and dimensions of the cooling body, owing to differences in the direction and intensity of convection currents. Péclet's formulae are:

For horizontal cylinders,

$$K' = 0.421 + \frac{0.308}{r} \quad . \quad . \quad . \quad . \quad . \quad (11)$$

For vertical cylinders,

$$K' = \left(0.149 + \frac{0.0443}{\sqrt{r}}\right)\left(2.43 + \frac{1.585}{\sqrt{h}}\right) \quad . \quad . \quad (12)$$

For cylinders inclined at the angle α to the horizontal,

$$K' = K' \text{ (hor.) } \cos \alpha + K' \text{ (vert.) } \sin \alpha \quad . \quad (13)$$

In these formulas, r is the radius in inches and h the height in feet. Tables 4 and 5 give values of K' computed from formulae (3) and (4).

TABLE 4.—CONDUCTION FACTOR K' FOR HORIZONTAL CYLINDERS.

Diameter, inches.	K'.	Diameter, inches.	K'.
2	0.729	12	0.472
4	0.575	14	0.465
6	0.524	16	0.459
8	0.498	18	0.455
10	0.483	20	0.452

The formulae and tables show that the conduction-loss is considerably smaller than the corresponding radiation-loss and that the former grows much more slowly than the latter with increased temperature-difference.

TABLE 5.—CONDUCTION FACTOR K' FOR VERTICAL CYLINDERS.

Diameter, inches.	Height of cylinder, feet.		
	5	10	20
2	0.607	0.567	0.537
4	0.565	0.528	0.501
6	0.549	0.513	0.487
8	0.537	0.501	0.476
10	0.530	0.495	0.470
12	0.524	0.490	0.465
18	0.515	0.481	0.457
24	0.509	0.475	0.451

Total Heat Loss.—The total loss is the sum of the values given by (9) and (10), or

$$M = R + A \quad . \quad . \quad . \quad . \quad . \quad . \quad (14)$$

Example: Uncovered wrought-iron pipe 6.3 inches outside diameter, saturated steam, pressure 186 pounds, absolute-temperature of steam, 375.4 degrees, of air, 87.1 degrees, temperature-difference, 288.3 degrees. Value of k (Table 2) = 0.568.

Radiation Loss, R.—(Tables 1 and 2).

At 59° air-temp. and 288° temp.-diff., . $R = 680.27\ K$
Addition for $0.3° = 3.836 \times .3 =$ . . . 1.15

At 59° air-temp. and 288.3° temp.-diff. . $R = 611.42\ K$

Factor for air-temp. $87.1° = 1.12 + 0.005\,(87.1 - 86) = 1.125$.
∴ at 87.1° air-temp., $R = 611.42 \times 1.125 \times 0.568 = 390.7$ B.t.u.

Conduction Loss, A.—From Table 3, at 288° temp.-diff., $A = 518.69\ K'$; the difference per degree is 2.226. From Table 4, for a 6.3-inch pipe:

$K'=0.524-0.3\ (0.524-9.509)=0.52.$

At 288° temp.-diff.	$A = 518.69\ K'$
Addition for $0.3° = 0.3 \times 2.226 =$ . .	0.67
At 288.3° temp.-diff.	$A = 519.36\ K'$

$\therefore A = 519.36 \times 0.52 = 270.07$ B.t.u.

Total Heat Loss: $M = R + A = 390.7 + 270.07 = 660.77$ B.t.u. per square foot per hour.

This is the minimum heat loss computed for the conditions of Péclet's experiments. As shown by Table 6, the correction, for the conditions of practice, ranges between 0.1 and 0.47. Taking 0.35 in this case, we have

Estimated Heat Loss $= 660.77 \times 1.35 = 892.04$ B.t.u. per square foot per hour, which is 96 per cent. of the actual heat loss as found by measuring the condensate.

III. Heat Losses of Uncovered Pipes.

Saturated Steam.—In Table 6, there are assembled the data of 19 of the principal tests of uncovered pipes containing saturated steam. The steam was in all cases motionless, except for the flow necessary to replace the condensate. The heat loss was considered to be the latent heat of the amount of this condensate which was properly chargeable to the pipe under test. The condensate was assumed to be discharged at the temperature of the steam. The loss per square foot of outer surface of pipe, as given in column 8 of the table, refers in general to that surface only, and not to the flanges and valve chambers of a steam pipe in actual service.

Column 9 gives the total losses as computed by Péclet's formulae, and column 10 shows that the average correction to be applied to the latter is 0.3. The necessity for this correction is obvious for two reasons: first, Péclet's results were derived from laboratory experiments on apparatus of limited size, under wholly controllable conditions as to air-currents and the exact measurement of the heat dissipated; second,

TABLE 6.—HEAT LOSSES OF SATURATED STEAM IN UNCOVERED PIPES.

Test No.	Pipe.		Steam pressure, lbs., abs.	Temperature, F.		Temp-diff. steam and air, deg. F.	Heat-loss per sq. ft. per hour, B.t.u.			
	Metal.	Diam., outside, ins.		Steam.	Air.		Actual.	Péclet.	Ratio $\frac{A}{P}$.	Per 1° F. of temp.-diff.
1	C.I.	6.2	74.7	307.1	76.1	231.0	596.02	502.44	1.19	2.58
2	"	2.39	74.2	306.6	75.4	231.2	642.74	566.38	1.14	2.78
3	"	2.39	94.7	323.7	50.5	273.2	841.46	681.05	1.23	3.08
4	"	2.39	164.7	365.7	60.5	305.2	1019.37	827.16	1.23	3.34
5	W.I.	3.53	17.7	221.5	64.8	156.7	360.63	287.82	1.25	2.301
6	"	3.53	39.7	266.7	69.2	197.5	433.9	393.35	1.10	2.197
7	"	6.3	47.4	277.3	78.3	199.0	528.41	379.13	1.39	2.655
8	"	3.0	45.1	274.4	61.0	213.4	574.16	438.69	1.31	2.691
9	"	3.53	54.7	286.5	68.5	218.0	595.7	448.41	1.33	2.732
10	"	6.3	96.0	324.7	89.1	235.6	687.45	492.65	1.39	2.918
11	"	3.53	73.7	306.2	62.6	243.6	697.19	519.21	1.34	2.862
12	"	3.53	84.7	315.8	69.0	246.8	785.4	534.24	1.47	3.182
13	"	3.0	93.7	322.9	63.0	259.9	753.87	582.13	1.29	2.901
14	"	3.53	100.7	328.1	68.0	260.1	775.9	576.24	1.35	2.983
15	"	8.5	125.2	344.3	75.5	268.8	728.45	563.49	1.29	2.71
16	"	3.53	114.7	337.7	65.3	272.4	859.6	613.39	1.40	3.156
17	"	7.64	164.0	365.4	92.3	273.1	807.4	606.55	1.33	2.956
18	"	6.3	185.9	375.4	87.1	288.3	933.2	660.77	1.41	3.237
19	"	3.0	185.5	375.3	71.1	304.2	962.35	748.31	1.29	3.163
				Means =		246.22			1.302	2.864

the possible errors of the condensate method under practical conditions, if not applied with extreme accuracy.

With regard to tests in general, the possible reasons affecting this lack of agreement are: (*a.*) Air currents not due to convection. This is a disturbing influence which exists to a greater or less extent in all tests under ordinary conditions. (*b.*) Inaccurate measurement of the amount of the condensate which is properly chargeable to heat loss from the pipe. Condensate produced by the attachments of the test-pipe should be carefully computed. Defective action of the separator will affect the amount of the condensate. Leaky steam traps will allow steam to filter through. Uncovered drip pipes and traps add unduly to the amount of the condensate. Unsuitable test apparatus. Some investigators seem to have disregarded the fact that radiation is a mutual action, and, further, that convection currents from two adjacent heated bodies may conflict. (*d.*) Minor causes are: inaccurate measurement of the loss due to flanges, valve chambers, etc., and relying on surface measurements—which are wholly untrustworthy—for the temperatures of the outer surface of a pipe or covering. The temperature of any such surface is not that of the film of air adjacent to it, which is what a thermometer measures to a greater or less extent.

TABLE 7.—HEAT LOSS IN B.T.U. PER SQUARE FOOT OF OUTER SURFACE OF PIPE PER HOUR.

Test No.	By radiation.			By conduction.			Total.		
	Stefan erle).	Péclet.	Ratio $\frac{S}{P}$	Eberle.	Péclet.	Ratio $\frac{E}{P}$	Eberle.	Péclet.	Ratio $\frac{E}{P}$
8	305.02	214.34	1.42	269.14	224.35	1.12	574.16	438.69	1.31
13	424.04	295.97	1.43	329.83	286.15	1.15	753.87	582.12	1.29
19	571.35	401.04	1.42	391.	347.27	1.13	962.35	748.31	1.29
7	294.15	208.17	1.41	234.26	170.96	1.37	528.41	379.13	1.39
10	404.88	282.07	1.44	282.57	210.58	1.34	687.45	492.65	1.39
18	555.46	390.7	1.42	377.74	270.07	1.39	933.2	660.77	1.41
	Means:		1.42			1.26			1.35

That there is a definite agreement between Péclet's results, —when suitably corrected for practical conditions,—and Stefan's law is shown by the data of Table 7.

These tests* are part of an extensive series conducted by Eberle under the auspices of the "Vereines deutscher Ingenieure." The total heat loss was measured by the condensate method. The radiation loss was computed by Eberle from Stefan's law, in the form:

$$R = 0.1406\left[\left(\frac{T}{100}\right)^4 - \left(\frac{T_0}{100}\right)^4\right]$$

in which, R, the radiation loss, is given in B.t.u. per square foot of pipe surface per hour and T and T_0 are respectively the absolute temperatures F. of the pipe and the air. The value of the constant K in Stefan's law was thus assumed arbitrarily to be 0.1406×10^{-8}. The conduction loss was taken as the difference between the total loss and that computed for radiation.

Although the steam pressure (Table 6) differed in each of the tests of Table 7, column 4 shows that the calculations by Stefan's law are almost uniformly 42 per cent. higher than those by Péclet's formulae, *i. e.*, that there is a constant relation between the two. The value of Eberle's constant may have been too high, that of Péclet's radiation constant too low, or both may be right and the difference may be due to that between the conditions of the two series of tests. The same uniformity does not exist in the figures for the total and conduction losses, since both depend on condensate measurements, with the errors possible in that method.

From Table 6, the total heat loss can be calculated, in fair approximation for any given case within the temperature range of that table, by computing it from Péclet's formulae and multiplying the result by the mean ratio given at the foot of column 5; or, by assuming the outside of the pipe to be at the temperature of the steam, and multiplying the difference

*"Zeits. d. Ver. deuts. Ing.," April 4, 1908.

between this temperature and that of the air by the factor given in column 6.

Superheated Steam.—Tests to find the heat loss of superheated steam in transmission are more difficult than those with saturated steam, because the steam velocity is a factor. For practical results, tests should be made only on moving steam at the velocity at which it is desired to ascertain the heat loss. The various factors of this complex problem are:

(*a.*) *Absolute and Proportionate Heat Losses.*—The absolute heat loss is the loss per square foot of outer surface of pipe per hour. The proportionate loss is the loss of heat per pound of steam transmitted. With higher velocity, the absolute loss is divided among a greater number of pounds of steam, making the proportionate loss less.

(*b.*) *High and Low Degrees of Superheat.*—According to the investigation of Richter*, highly superheated steam simply loses some of its superheat during transmission. Hence, the only method of ascertaining its heat losses is to find the average quality of the steam at entrance to and at exit from the pipe. This determination is difficult, since it involves temperature measurements at various points in the cross-section of the column of steam. With low superheat an absolutely accurate determination is impossible, owing to the formation of condensate, some of which will be entrained by the swiftly moving steam, and, passing through the separator, will escape measurement.

(*c.*) *Temperature of the Pipe.*—Pipe temperature is the principal factor affecting heat loss. With saturated steam, this temperature is very close to that of the steam. With superheated steam, there is a marked difference between the two temperatures, the temperature fall from the center to the circumference of the pipe depending mainly on the steam velocity. At high velocity, the steam has little time to cool and the proportionate loss is less than at low speed. But the temperature fall is also less, the pipe temperature higher, and

* "Zeits. d. Ver. deuts. Ing.," Feb. 24, 1906.

the absolute loss greater. At low velocity these effects are reversed throughout.

In view of these various factors, it is clear that with superheated steams at the same temperature there may be absolute and proportionate losses which will differ widely. Tests based on steam temperature or steam velocity only are of no service. The number of available tests is limited. The data* given in Table 8 are fairly representative for the velocity and temperature range tabulated. These tests were made on an uncovered pipe, 2.76 inches internal diameter and 87 feet 2 inches long. The pressure during the series averaged 96 pounds, absolute. The coefficient k_1 of external conductivity of steam to pipe metal was taken as 30.75.

TABLE 8.—HEAT LOSSES OF SUPERHEATED STEAM IN BARE PIPES.

Computed for a steam velocity of 4,920 feet per minute and an air temperature of 68 degrees F.

Temperature, degrees F. of		Temperature-difference between steam and		Heat loss per square foot of outer surface of pipe per hour, B.t.u.
Steam.	Pipe.	Air.	Pipe.	
347	320.0	279	27.0	823
392	359.6	324	32.4	1,018
437	397.4	369	39.6	1,225
482	435.2	414	46.8	1,450
527	471.2	459	55.8	1,697
572	509.0	504	63.0	1,956
617	545.0	549	72.0	2,232
662	579.2	594	82.8	2,531
707	615.2	639	91.8	2,841
752	649.4	684	102.6	3,170

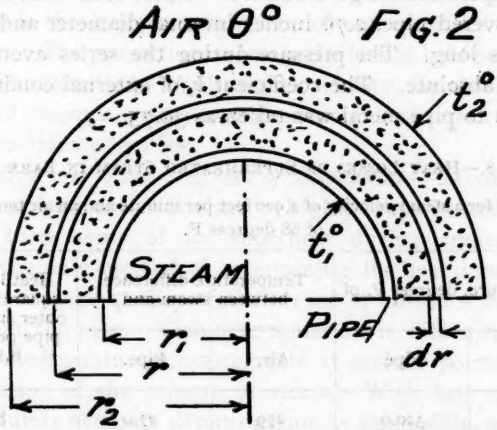
It should be observed that the temperature of the pipe was found, for the assumed value of k_1, by equations (3), etc., as given herein, and the heat losses by applying the same methods as those used for saturated steam, thus assuming that for the same pipe temperature the heat-emissivities of stationary saturated steam and of superheated steam at the

*"Zeits. d. Ver. deuts. Ing." March 28, 1908.

velocity given, are the same. These assumptions affect the absolute accuracy of the results, but their effects are minor.

IV. HEAT LOSSES OF COVERED PIPES.

By the use of Péclet's formulae, the efficiency of a covering can be ascertained, if the conductivity is known, and the conductivity, if the heat loss has been found, both in reasonable approximation. The general method is as follows:



In Fig. 2, let r_1 and r_2 be respectively the internal and external radii of the covering, t_1 and t_2 the corresponding temperatures, θ the temperature of the air, C the conductivity, and M the total heat loss. This loss must be equal to the amount of heat traversing an elementary annulus of radius r, width dr, and temperature fall dt. Then, by equation (1), we may write:

$$M = -\frac{2\pi r\, C dt}{dr}, \text{ from which}$$

$$Cdt = -\frac{M dr}{2\pi r}.$$ Integrating between the limits, t_1, t_2, and r_1, r_2, and transforming:

$$M = \frac{2\pi C(t_1 - t_2)}{N} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (15)$$

in which, $N = m(\log r_2 - \log r_1)$ and $m = 2.3025$, the modulus of the Napierian system.

Again, Newton's law of cooling is true for very small temperature-differences only. Assuming that it is universally true, we may write:

$$M = 2\pi r_2 Q(t_2 - \theta) \quad . \quad . \quad . \quad . \quad . \quad (16)$$

in which $Q = K + K'$, *i. e.*, the sum of the radiation and conduction coefficients for the covering, as given in Tables 2, 4 and 5. Combining (15) and (16), we have:

$$M = \frac{2\pi r_2 QC(t_1 - \theta)}{C + Qr_2 N} \quad . \quad . \quad . \quad . \quad . \quad (17)$$

which is the general formula giving the approximate heat loss on the assumption as above with regard to Newton's law.

Analysis of this formula will show that the heat loss does not decrease inversely as the thickness of the covering but in a less degree, since the extent of surface exposed to radiation and conduction is a factor. Hence, doubling the thickness will reduce the loss by nearer one-third than one-half of the original amount. Again, it can be shown that, when the value of C is very low, M decreases rapidly with growing thickness, until a limit is reached when the increased size of the radiating surface will neutralize the resistance of low conductivity and M will grow with greater thickness.

Example.—Horizontal cast iron pipe, 3 inches nominal diameter; saturated steam at 293 degrees F.; air temperature 59 degrees; covering, one inch thick of asbestos cased with canvas; conductivity C of covering = 0.48 for block one foot square and one foot thick.

Heat Loss of Bare Pipe.—Temperature of pipe = that of steam; temperature-difference = 293 − 59 = 234 degrees; for cast iron (Table 2) $K = 0.65$. Radiation loss (Table 1) = 430.79 × 0.65 = 280.01. By formula (11), $K' = 0.626$. Conduction loss (Table 3) = 401.54 × 0.626 = 251.36. Total heat loss = 280.01 + 251.36 = 531.37 B.t.u. per square

foot of pipe surface, and, per running foot of pipe = 416.6 B.t.u.

Heat Loss of Covered Pipe.—$t_1 - \theta = 293 - 59 = 234$ degrees. Taking all dimensions in feet and pipe as nominal size, $r_2 = 0.229$ foot, $C = \frac{0.48}{12} = 0.04$, $N = 0.451$. $Q = K + K'$, these constants being for the covering. By Table 2, K for canvas = 0.75. By formula (11), $K' = 0.544$. Hence, $Q = 1.294$. Substituting in formula (17):

M (per square foot of covering surface) = 97.7 B.t.u.

M (per running foot of covering surface) = 127 B.t.u.

$$\text{Economy of covering} = \frac{(416.6 - 127)}{416.6} = 70 \text{ per cent.}$$

These values of M are approximate, because we have assumed Newton's law to be true for all temperature-differences, and, on this assumption, have taken the coefficients of K and K' as unity and $Q = K + K'$. This assumption is valid only for very small differences of temperature between the cooling body and the surrounding air.

The true value of M can be found, however, from these results by a series of approximations, since from the approximate M just deduced, we can ascertain the corresponding approximate temperature of the surface of the covering. The method is as follows:

Data.—First value of $M = 127$; area of one running foot of surface of covering = 1.44 square feet; radius of outside of covering = 0.229 foot; temperature $t_1 = 293$ degrees; air temperature = 59 degrees; K (canvas) = 0.75; $K' = 0.544$; $Q = 1.294$; $C = 0.04$; $N = 0.451$.

(1.) Substituting in formula (16):

$$t_1 - 59 = 68 \text{ degrees and } t_1 = 127 \text{ degrees.}$$

(2.) To find the coefficients of K and K' for 68 degrees temperature-difference, divide the total coefficients given by Tables 1 and 3 by 68. Thus:

$$\text{Coefficient of } K = \frac{(64.96 + 1.403 \times 14)}{68} = 124.$$

$$K' = \frac{(65.88 + 1.56 \times 14)}{68} = 1.29.$$

Then the new value of Q is:

$$Q' = 1.24\,K + 1.29\,K' = 1.632.$$

(3.) Substituting the value of Q' in formula (17), we have the corresponding value:

$$M' = 105 \text{ B.t.u.}$$

(4.) To find the corresponding surface temperature t_2', we have from formula (16):

$$t_2' - 59 = \frac{105}{1.44 \times 1.632} = 45 \text{ degrees, and } t_2' = 104 \text{ degrees.}$$

(5.) For a second approximation, repeat the processes as above. Thus, repeating method (2) for a surface temperature-difference of 45 degrees:

$$Q'' = 1.186\,K + 1.176\,K' = 1.529.$$

This value of Q'' gives by method (3),

$$M'' = 104.3 \text{ B.t.u.},$$

which is only 0.7 B.t.u. less than M'. It may therefore be accepted as final. This result, like those computed for bare pipes, is subject to a correction to meet the conditions of pipes in service.

In finding the conductivity C of a covering from test results, the values of M and t_1 (for saturated steam) are known, and the surface temperature t_2 can be computed by the method of approximation employed above. Substituting these values in formula (15) gives that of C.

Table 9 gives some representative tests of pipe coverings by the condensate method. From these data, the conductivity and economy of the various coverings can be computed for comparison by the methods just described.

TABLE 9.—CONDENSATE TESTS OF PIPE COVERINGS.

(Saturated Steam.)

Investigator.	Pipe diameter.	Covering. Material.	Covering. Thickness.	Temperature. Air.	Temperature. Steam.	Economy: Heat saved, as compared with bare pipe, per cent.
	Inches.		mm.	Degs.	Degs.	
Pasquay	.....	Silk waste	26.	15 C.	135 C.	85.6
Pasquay	.....	Silk waste and air jacket	39	15 C.	135 C.	87.9
Brill	8	Hair felt	0.82	69 F.	348.3 F.	84.4
Brill	8	Mineral wool	1.3	58.3 F.	344.1 F.	81.4
Haacke	5	Kieselguhr*	1.0	76.1 F.	307 F.	83.6
Capper	.....	Mica†	1.6	.....	404.2 F.	89.3
Barrus	10	Asbesto-sponge felt	1¼	62.8 F.	364.8 F.	91.3
Barrus	10	Magnesia	1⅞	66 F.	365.2 F.	89.0
Barrus	10	Asbestos, Navy brand	1½	66.8 F.	365.2 F.	88.0
Jacobus	2	Remanit‡	1.3	76.1 F.	306.6 F.	86.9
Jacobus	2	Asbestocel	1.07	77.2 F.	301.8 F.	77.2
Jacobus	2	Asbestos air cell	0.96	72.3 F.	303.3 F.	74.4
Jacobus	2	Asbestos fire felt	1.2	72.5 F.	307.4 F.	73.1
Jacobus	2	Magnesia	1.08	81.6 F.	310.9 F.	83.2
Bolan and Grieve	3	Slag wool	1.25	.....	308.1 F.	79.4
Bolan and Grieve	3	Magnesia, sectional	1.5	.....	308.1 F.	80.5
Zulauf	7.56	Snowdon's asbestos composition	2.28	83.3 F.	366.0 F.	89.2
Zulauf	7.56	Compressed cork, Frick's	2.76	85.1 F.	366 F.	88.6
Zulauf	7.56	Isolgurit§	2.28	85.1 F.	366 F.	83.6

* Fossil meal composition.
† Made in flat or curved mattresses enclosed between casings of wire netting.
‡ Braids or pads of carbonized silk; pads enclosed in a net work of fine wire.
§ In fusorial earth with fibers.

In Table 10, there are assembled some covering tests made by other than condensate methods. For example, Norton's tests were conducted on a pipe filled with oil, heated electrically by coils of wire immersed in it. The method of Benisch and Anderson was similar, except that the closed pipe contained air instead of oil. In Stott's tests, the pipe was closed and filled with air, but it was heated directly by insulated cables soldered to its ends.

Electrical tests, especially those by the direct method, give an accurate measurement of the heat passing through the covering, thus avoiding the uncertainty and possible error of the condensate method. The basic principle governing them is that, if R be the resistance of any conductor at a given temperature, the energy required to maintain it at that temperature is C^2R, in which C is the measured current. If C_b be the current required for the bare pipe and C_c that for the covered pipe, then the B.t.u. saved per hour by the covering are:

$$3.41\ R(C^2_b - C^2_c).$$

It should be observed, however, that, while such tests measure accurately the conductivity and economy, they have no relation to steam transmission, in which the heat loss is affected by the coefficient of heat emissivity of the steam, and, if the latter be superheated, by its velocity also.

A method of heat insulation which has received less attention than its merits, is the use of air jackets which encase the pipe with a film of air too thin for convection to be a serious factor. It is the entrapped air in their more or less cellular structure which produces the economy of most pipe covering materials. With regard to air jackets of sheet-tin or zinc, Russner* says:

"I have found in my experiments that, at a steam pressure of one atmosphere, the most favorable thickness of the air stratum or the distance between pipe and jacket, is about 15 mm. With such a distance I have succeeded in reducing the quantity of water of condensation 74 per cent., and, with two jackets, 85 per cent."

TABLE 10.—ELECTRICAL TESTS OF PIPE COVERINGS.

Investigator.	Pipe diameter.	Covering.		Temperatures deg. F.		B.t.u. lost per sq. ft. of pipe surface, per minute.	Economy: heat saved by covering, per ct.
		Material.	Thickness.	Air.	Pipe.		
	Inches.		Inches.				
Norton	4	Bare pipe	.....	72.0	388.0	13.84	0.0
Norton	4	Nonpareil cork	1.00	72.0	388.0	2.20	84.1
Norton	4	Manville high pressure	1.25	72.0	388 0	2.38	82.8
Norton	4	Magnesia	1.12	72 0	388.0	2.45	82.3
Norton	4	Imperial asbestos	1.12	72.0	388.0	2.49	82.0
Norton	4	Calcite	1.12	72.0	388.0	3.61	73.9
Stott	2	Bare pipe	.....	84.2	370.4	13.08†	0.0
Stott	2	No. 2	1.5	84.2	370.4	1.672	87.2
Stott	2	No. 6	1.0	84.2	370.4	1.371	89.5
Stott	2	No. 19	2.0	84.2	370.4	1.463	88.8
Stott	2	No. 20	2.0	84.2	370.4	1.544	88.2
Stott	2	No. 21	2.0	84.2	370.4	1.562	88.0
Benisoh and Andersen	.....	Bare pipe	.....	.....	356.0	10.25	0.0
	.....	Kalorit	0.787	.....	356.0	4.43	56.8

†Computed from Péclet's formulae by the author. Covering No. 2: granulated cork, moulded and baked; No. 6: nine layers of asbestos paper with granulated cork in between; No. 19: eighty-five per cent. carbonate of magnesia in two one-inch layers; No. 20: solid two-inch moulded sectional covering, composed of eighty-five per cent. magnesia, finished with canvas; No. 21: same form and composition as No. 20.

*"Power," December, 1896.

PANAMA COLLIERS *ULYSSES* AND *ACHILLES*.

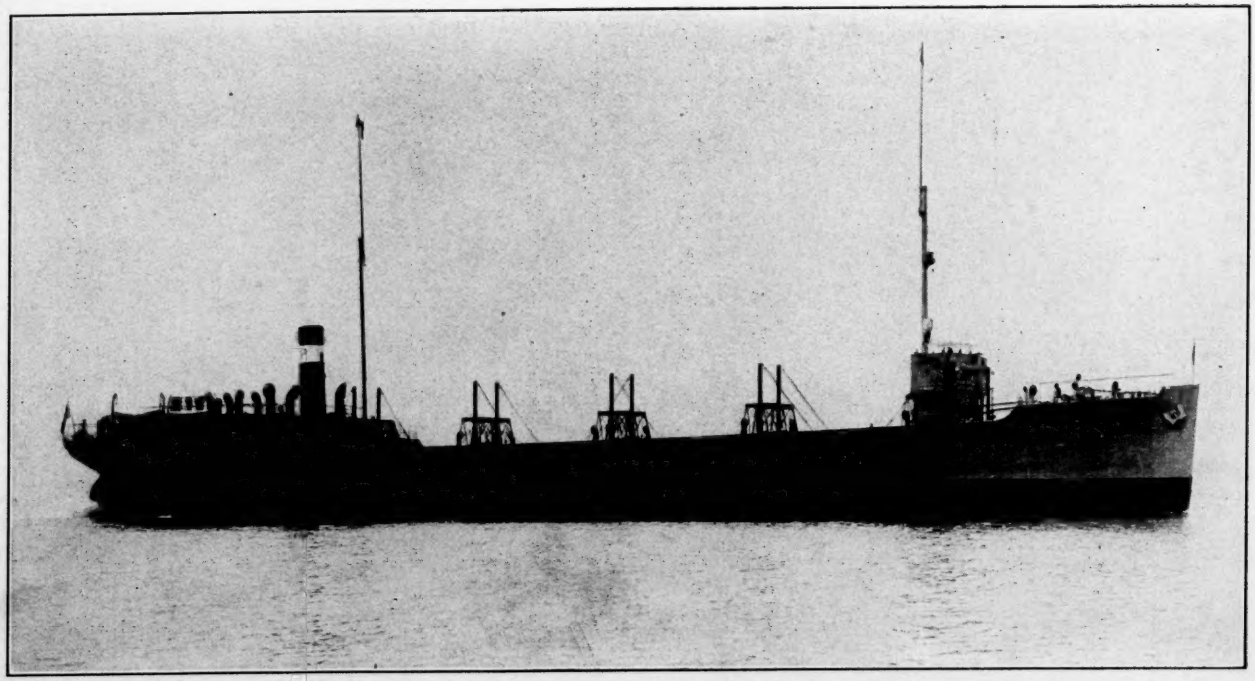
DESCRIPTION AND CONTRACT TRIAL PERFORMANCE.

By Henderson B. Gregory, Associate.

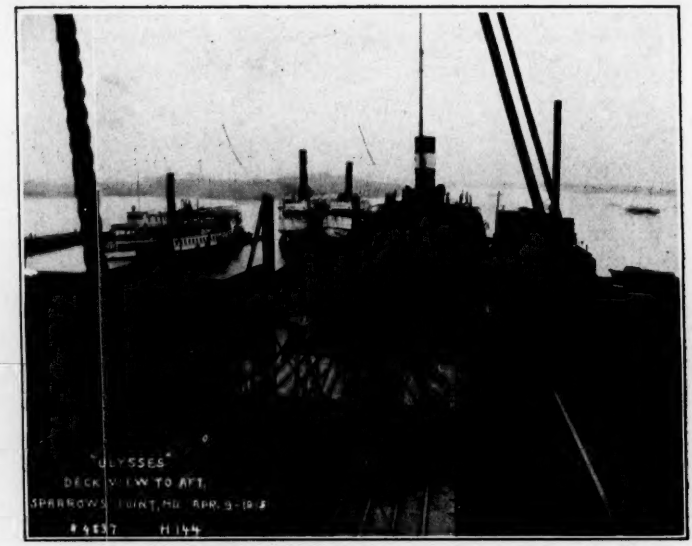
There have recently been completed and placed in commission two large colliers, the *Ulysses* and *Achilles*, for the Panama Canal.

The vessels were authorized by an Act of Congress, approved June 23, 1913, and were built under contract by the Maryland Steel Company, of Sparrow's Point, Maryland, in accordance with plans and specifications prepared by the Navy Department. The contract price was $987,500.00, each, and the time of completion sixteen months from date of contract, April 9, 1914. They are twin-screw vessels, driven by reciprocating engines of 7,200 combined I.H.P., and designed for a speed of 14 knots at a displacement of about 19,585 tons, corresponding to the vessel complete, with all equipment, as usually carried on board in service; and with 12,000 tons of cargo coal, 1,200 tons of bunker coal, 20 tons of reserve feed water, 10 tons of drinking water, 75 tons of stores and crew. Provision is also made for carrying cargo fuel oil, when desired.

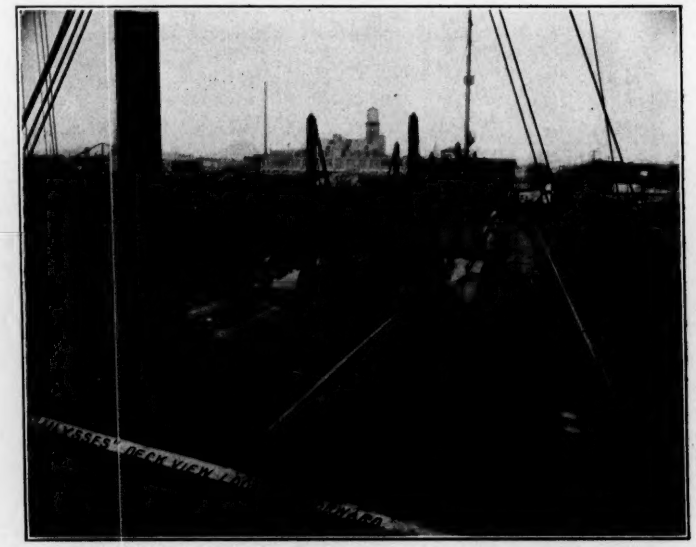
The construction of the vessels was in conformity with the Lloyd's Classification Society Rules and the United States Steamboat Inspection Rules, except as modified by the detail specifications. The vessels were inspected during construction by the Navy Department and representatives of the above-named organizations, and upon completion each vessel was furnished with a Certificate of Classification Lloyd's Register of Shipping for a vessel to Class 100–A–1, Lloyd's for American Government Service, Special Survey, and also a Certificate of Equipment that the vessel complies with the United States Steamboat Inspection Laws.



"Ulysses" on Trial Trip, Sparrow's Point, Md., April 10, 1915.



"Ulysses," Deck View Looking Aft.



"Ulysses," Deck View Looking Forward.

PRINCIPAL HULL DIMENSIONS.

Length over all, feet and inches	536–0
between perpendiculars, feet and inches	514–0
on load water line, feet and inches	514–0
Beam, extreme, feet and inches	65–2½
on load water line, feet and inches	65–2½
moulded, feet and inches	65–0
Mean designed draught, feet and inches	27–10
Displacement at designed draught, tons	19,414
per inch at L. W. L., tons	64.2
Area of immersed midship section at designed draught, square feet	1,780
L. W. L. plane at designed draught, square feet	26,600
Wetted surface at designed draught, square feet	47,320
Coefficient of fineness, block	0.724
midship section	0.984
load water line	0.8

GENERAL DESCRIPTION OF HULL.

The vessels are of steel, single-deck, self-trimming type, with topside ballast tanks and raised forecastle and poop deck. There are two masts and one smoke pipe.

Navigating Bridges.—There are two bridges located just abaft of the forecastle deck. The upper bridge is open and fitted with steering gear and searchlight platform, on which is mounted one searchlight. The lower bridge is semi-inclosed with steering platform in center, and chart house and bridge cabin, port and starboard, respectively. Below the lower bridge is the radio room.

Forecastle Deck.—This deck extends from the bow about 50 feet aft, and on it are located the anchor windlass and minor deck fittings.

Poop Deck.—The poop deck is about 175 feet long. On this deck is located a spacious deck house containing the officers' quarters, officers' and crew's galleys, pantries and bakery. There is also a small steam capstan aft of the deck house.

On top of the deck house are carried the boats.

Main Deck.—The main deck is continuous from the stem to the stern. It is a weather deck between the limits of the fore-

castle and poop decks. Under the forecastle are located the lamp room, paints and oils room, windlass engine, and crew's water closets and wash room. On the weather portion of the deck are the hold hatches and winches. Aft under the poop deck are the executive officer's and chief engineer's offices, crew's and firemen's wash rooms and water closets, crew's and chief petty officers' quarters, hospital and steering-gear room.

1st Platform.—Forward are a storeroom and spare berthing space, and chain lockers; and aft are located the engineer's workshop and stores, refrigerating and dynamo machinery, crew's berthing space and stores.

2d Platform.—The space forward is completely occupied by storerooms and chain lockers; and aft are located the refrigerating rooms, stores, fresh-water tanks and trimming tanks.

Hold.—From forward aft the hold contains the following: Forward trimming tank, pump room, holds for stores or cargo-oil, cargo-coal holds, steaming-coal bunkers and boiler room, engine room and the after trimming tank. Under the boiler and engine rooms are located the reserve feed and fresh-water tanks, respectively.

BOATS CARRIED.

The following small boats are carried in cradles on top of the deck house. The davits are of the Welin quadrant type:

3 28-foot metallic lifeboats;
1 30-foot self-righting and self-bailing motor lifeboat;
1 20-foot working boat;
1 14-foot punt;
Life rafts as necessary to provide for the remainder of the complement.

DECK MACHINERY.

Anchor Windlass.—An American Engineering Company's steam anchor windlass is located on the forecastle, with engine below on the main deck. The engine is of the vertical type with two steam cylinders 12 inches diameter by 14 inches stroke each.

Steering Engine.—The steering engine is located on the main deck aft. It is the American Engineering Company's horizontal type with two steam cylinders 12 inches diameter by 12 inches stroke each.

Capstan.—Aft of the deck house on the poop deck is an American Engineering Company's capstan operated by a horizontal steam engine with two cylinders 8 inches diameter by 8 inches stroke each.

Deck Winches.—There are eight steam deck winches on the weather portion of the main deck, for handling hatch covers, etc. The forward winch differs in design from the others, being equipped for serving the forward cargo holds. All winches were supplied by the American Engineering Company. They are of the horizontal double-cylinder type, cylinders 8 inches diameter by 8-inch stroke.

VENTILATION.

Cowls in number, location and size, as required for an efficient system of natural ventilation, are provided.

HEATING SYSTEM.

All living spaces, offices, bridge houses and quarters are steam heated in accordance with the usual practice.

STEAM FIRE-EXTINGUISHER SYSTEM.

A steam fire-extinguisher system is provided, consisting of 1½-inch independent connections to each hold and inner bottom tank. Steam is taken off the deck auxiliary steam line with a stop valve at each connection.

FIRE MAIN.

The fire main is supplied by a 6-inch connection from the fire and bilge pump, one of 8 inches from the ballast pump and

a 5-inch connection from the ash ejector pump. The fire main and topside ballast system are in common. Varying in diameter from 6 to 3½ inches, it extends fore and aft on the main deck, port and starboard, with hose valves conveniently located on the mains, and branches to the various parts of the vessel requiring hose plugs for fire protection and general purposes. All hose plugs are for 2½-inch standard fire hose.

DRAINAGE, PUMPING AND FLOODING SYSTEMS.

The customary drainage, pumping and flooding system is provided for the double-bottom tanks, topside ballast tanks, peak tanks and compartments requiring drainage. The tanks are filled and emptied by the pumps in the engine room and pump room forward. The topside ballast tanks drain overboard direct, through valves operated from the weather deck.

The topside ballast tanks on each side of the vessel are filled from the firemain, there being a branch with valve to each tank. The firemain has a branch forward for filling the forepeak tank.

The usual strainers are fitted in all drainage suction pipes to guard against coal dust, dirt, etc., choking the pipes, or entering the manifolds and pumps.

The double-bottom reserve feed tanks have connections only to fresh-water and feed pumps, and have filling pipes from the ship's side.

SANITARY SALT AND FRESH-WATER SYSTEMS.

The salt-water flushing system is supplied by the flushing, fire and bilge and distiller circulating pumps in the engine room. It supplies salt water to all water closets, galleys and to the firemen's and crew's lavatories and showers.

The fresh-water system is supplied by a gravity tank on top of the poop deck house, which is filled by a fresh-water pump located in the engine room. The fresh-water main supplies bath rooms and lavatories, pantries, galleys, scuttle butts, bakery, hospital, etc.

Individual water heaters are provided in bath rooms, etc., as required.

The ship's fresh-water tanks are located on the 2d platform aft. They have filling connections from the distilling apparatus and the ship's side, and suction connections to the fresh-water pump in the engine room.

CARGO FUEL—OIL SYSTEM.

The holds forward and inner bottom tanks, beneath the cargo coal holds, are fitted for carrying fuel oil when desired;

TABLE I—PUMPS AND CONNECTIONS—PANAMA COLLIERS ULYSSES & ACHILLES.

No.	Pumps	Size (Ins.)	Type	Suction Pipes from		Discharge Pipes to		Location
				Ins.		Ins.		
2	Main Air	22 x 18	Attached	8	Condenser.	3	Feed Tank.	Eng. Room.
						8	Relief Valve.	
2	Main Circulating	14" Nozzles	Vertical, Single, Centrifugal. 10 Cyl. 2 3" Strons. 39" Impeller.	14	Sea.	14	Condenser.	Do.
				10	Bilge.			
				10	Cross-Connection.			
2	Main Feed	14 x 9 x 24	Vertical, Piston, Double-Acting, Single. "Warren."	5	Feed Tank.	4	Main Feed Discharge.	Do.
				5	Reserve Feed Tanks.			
1	Aux. Feed	Do.	Do.	5	Feed Tank.	4	Main Feed Discharge.	Do.
				5	C. & R. Pipes from Ship's Side.	4	Aux. Feed Discharge.	
						4	Reserve Feed Tanks.	
				5	Reserve Feed Tanks.	2½	Overboard.	
				2	Boiler Blow Pipe.			
				3	Channelway.			
1	Aux. Boiler Feed	6 x 4 x 8	Do.	2	Feed Tank.	1½	Aux. Boiler.	Do.
				2	Reserve Feed Tanks.	1½	Aux. Feed Discharge.	
1	Fire and Bilge	12 x 14 x 12	Do.	8	Sea.	6	Fire Main.	Do.
				8	Drainage.	7	Overboard.	
				4	Bilge.	2½	Hose Connection.	
				18	Hose Connection.	2½	Distillers.	
						4	Flushing System.	
						3	Water Service.	
4	Bilge	5 x 18	Attached.	3½	Bilge.	3	Overboard.	Do.
				1½	Hose Connection.			
1	Flushing	8 x 8 x 12	Vertical, Piston, Double-Acting, Single, "Warren."	5	Sea.	4	Fire Main.	Do.
						4	Flushing System.	
						3	Water Service.	
						2½	Hose Connection.	
1	Aux. Air	7½ x 14 x 10	Vertical, Single, Double-Acting, "Warren."	6	Aux. Condenser.	5	Feed Tank.	Do.
1	Aux. Circulating	6" Nozzles 6 x 6" Emc.	Centrifugal, Single Engine.	6	Sea.	6	Aux. Condenser.	Do.
1	Evaporator Feed	4½ x 6 x 6	Vertical, Piston, Double-Acting, Single, "Warren."	2	Sea.	2	Evaporators.	Do.
				2	Overboard Disch. from Distillers.			
				2	Main Condenser Disch.			
1	Distiller Fresh-Water	Do.	Do.	2½	Bottom of Distillers.	2½	Fresh Water Tanks.	Do.
				2½	Test Tank.	1½	Main Feed Tank.	
				2½	Fresh Water Tanks.	2½	Reserve Feed-Water Tanks.	
						2½	Fresh-Water Main.	
1	Distiller Circulating	8 x 8 x 12	Do.	3½	Sea.	2½	Distillers.	Do.
						2½	Sanitary System.	
						1½	Refrigerating Machine.	
1	Ash Ejector	14 x 8½ x 12	Vert. Piston, D-A, Duplex, "Warren."	5	Sea.	5	Ash Ejector.	Boiler Room.
						5	Fire Main.	
1	Ballast Pump	12 x 14 x 12	Do.	10	Ballast.	10	Overboard.	Eng. Room.
				10	Sea.	8	Fire Main.	
				4	After Peak Tank.	6	Ballast Tanks.	
2	Cargo Oil	14 x 12 x 18	Do.	6	Oil Holds.	6	Oil Holds.	Pump Room Fwd.
				8	Sea.	10	Deck.	
				5	Double-Bottom Oil Tanks.	4	Overboard.	
						5	Double-Bottom Oil Tanks.	
				4	Fwd. Drainage Manifold Deck. (Ship's Side.)			
				6				
1	Brine Circulating	4½ x 3½ x 4	Horizontal, Duplex, Double-Acting, "Worthington."	2½	Brine Return (Surge Tank.)	1½	Brine Supply for Cooler	Ice Machine Room.

the total capacity being about 757,500 gallons. The oil is handled by two large pumps, located in the pump room forward, with connections as given in Table I. There are two 8-inch filling pipes from the ship's side forward connected to the pumps' suctions, and four 6-inch combined gravity filling and deck discharge connections on the main deck forward.

MAIN ENGINES.

The main propelling machinery consists of two vertical, inverted, direct-acting, three-cylinder, triple-expansion engines, placed abreast, port and starboard, in a common compartment. The engines turn outboard when running ahead. They are designed to develop about 7,200 I.H.P. when running at 98 revolutions per minute, with a steam pressure at the H.P. valve chest of 195 pounds gage.

The sequence of cranks is H.P., L.P. and I.P., all crank angles being 120 degrees.

The cylinders are of cast iron, the H.P. alone being fitted with liners, and none are jacketed.

The housing and bedplates are of cast iron, the former of the inverted Y-frame type bolted to the cylinders and bedplates at top and bottom, respectively, and carrying the crosshead guides. The latter are of the box-section type, faced for the reception of the housings and supporting the main bearings, which are lined with white metal.

All pistons are of cast iron of the flat box-section design, fitted with packing rings and followers.

The piston rods and connecting rods are of forged steel. To the former are secured forged-steel crossheads of the double-slipper type, which in turn carry the crosshead slippers, of cast iron and lined with white metal, on both the go-ahead and backing faces.

The valve gear is Stephenson double-bar links, with linking-up screws for adjusting the cut-off. The H.P. and I.P. cylinders have one piston valve each, and the L.P. cylinder two

piston valves. All valves are provided with balance pistons. The eccentric rods and valve stems are of forged steel, actuated by cast-iron eccentrics secured to the crank shafts. The eccentric straps are of cast steel lined with white metal.

All piston rods and valve-stem stuffing boxes are metallic packed.

Reversing Gear.—Each engine is provided with a reversing engine of the direct-acting type connected through connecting rods to the reversing-shaft arms, the shaft in turn connecting to the links by arms and suspension rods. The gear is controlled by a floating lever operated at the working platform.

Turning Gear.—The customary turning gear is fitted on each engine, consisting of a single-cylinder engine with cylinder 6 inches diameter by 6 inches stroke, driving an intermediate worm shaft, which engages a worm wheel driving a shaft connected to a secondary worm driving a worm wheel attached to the main-engine crank shaft.

Lubricating Gear.—All working and moving parts of the main engines are efficiently lubricated by wick-feed distribution boxes located on the main cylinders and fitted with brass tubes leading to the various parts requiring lubrication.

Water Service.—A water service is provided for the main bearings, crank pins, crosshead guides and pins, and the thrust bearings.

Main Engine Data.

Diameter of H.P. cylinder, inches	27½
I.P. cylinder, inches	46
L.P. cylinder, inches	76
Stroke, inches	48
Piston rod, diameter, inches	7⅛
Connecting rod, diameter, crosshead end, inches	7¼
crank end, inches	8¼
length between centers, inches	111
crank ratio	1:4.625
Diameter, throttle valve, inches	9
1st receiver pipes (2), inches	9
2d receiver pipe, inches	18
Main exhaust pipe, inches	21 x 27¼

Valve settings from diagram :	H.P.		I.P.		L.P.	
Number of piston valves	1		1		2	
Diameter of valves, inches	13½		25		25	
Travel of valves, inches	9		9		9	
Inside or outside steam	Inside.		Outside.		Outside.	
	Top.	Bot.	Top.	Bot.	Top.	Bot.
Width of port, inches	3	3	3½	3½	3½	3½
Steam opening, linear, inches	2 17/32	2 21/32	2⅝	2 9/16	2 11/32	2 15/32
Steam opening, mean area, sq. ins.	80.05		155.17		294.6	
Exhaust opening, linear, inches	3	3	3½	3½	3½	3½
Exhaust opening, area, sq. ins.	92.59		220		428.53	
Steam lap, inches	1 13/32	1 13/32	2⅛	1 1/16	2 5/32	2 1/32
Exhaust lap, inches	−⅜	−1/16	−⅛	0	−9/32	+1/32
Steam lead, linear, inches	⅜	1/32	1/16	⅛	⅛	3/32
Cut-off, decimal of stroke	80.72	74.38	77.05	70.77	74.11	66.33

SHAFTING AND BEARINGS.

There are two lines of shafting of three sections each supported by proper bearings. The crank shafts are of the built-up type, and of solid forged steel throughout. The thrust and tail shafts are solid forged steel, the latter being composition cased in wake of the stern tube and bearings.

The crank and thrust shafts have disc couplings, forged solid with the shafts, and secured together by taper bolts. Each tail-shaft coupling consists of a forged steel sleeve, secured to the shaft by two feather-keys, forward of the sleeve are two half collars fitting a groove turned in the end of the shaft, all through bolted to the after coupling on the thrust shaft by parallel bolts.

Shaft Data.

Crank shafts, diameter, inches	14⅞
length, feet and inches	23–7½
number of cranks	3
throw of cranks, inches	24
angle between cranks, degrees	120
Crank pins, diameter, inches	15
length, inches	16
Coupling discs, diameter, inches	27
thickness, inches	04½
bolts, number each coupling	8
diameter at face of coupling, inches	03⅛

Thrust shafts, diameter, inches	14⅞
length, feet and inches	18–0⅞
collars, number	8
thickness, inches	02⅝
space between, inches	05¼
outside diameter, inches	24½
inside diameter, inches	15
bearing surface, sq. ins	2,212.88
Tail shafts, diameter, inches	15⅝
length, feet and inches	51–5⅞

Bearing Data.

Crank-shaft bearings (White metal lined):	
Number, each shaft	6
Diameter, inches	14⅞
Length, inches	17¼
Thrust bearings (White metal lined bearings and shoes):	
Diameter, inches	14⅞
Length, inches	16
Thrust shoes, number each	8
effective surface, sq. ins	1,548.8
Stern-tube bearings (Lignum vitae lined):	
Forward, diameter, inches	17⅛
length, inches	22
After, diameter, inches	17 3/16
length, inches	57¾
Strut bearings (Lignum vitae lined):	
Diameter, inches	17¼
Length, inches	64¾

PROPELLERS.

There are two true-screw three-bladed propellers of the adjustable-pitch and detached-blade type. The hubs are cast steel and the blades manganese bronze. The propellers have a taper fit on the tail shafts, and are secured by a key and nut.

Propeller Data.

Diameter, feet and inches	17–0
Pitch as set, feet and inches	17–0
Pitch	adjustable from 16 ft. to 18 ft.
Ratio of diameter to pitch	1
Projected area, square feet	81
Helicoidal area, square feet	94.29
Disc area, square feet	226.98
Height of lower tip of blade above keel, inches	18
Immersion of upper tip of blade at load draught, inches	114

MAIN CONDENSING APPARATUS.

Main Condenser.—There are two independent, cylindrical, surface, main condensers located one outboard of each main engine. The shells are steel plate, heads cast iron, tube sheets rolled brass, and tubes solid-drawn brass, No. 16 B.W.G. thick, ⅝-inch outside diameter and 10 feet 1 inch long between tube sheets. The tubes are secured in the tube sheets by the usual screw glands and packing. There are 3,213 tubes in each condenser, giving a total cooling surface in each of 5,301 square feet.

Particulars of the main air and circulating pumps are given in Table I.

Feed and Filter Tank.—A feed and filter tank is located in the forward port end of the engine room. The tank is divided into four compartments, with a filter chamber in the top of the second, third and fourth compartments.

ENGINE-ROOM AUXILIARIES.

Auxiliary Condenser.—There is one auxiliary condenser of similar construction to the main condensers. It contains 808 tubes and the cooling surface is 925.16 square feet.

Pumps.—The various engine-room pumps and their connections are enumerated in Table I.

Feed-Water Heater.—A Reilly multicoil feed-water heater, of 241.8 sq. ft. of H.S., is located in the port forward corner of the engine room, above the feed pumps. It is connected to the main feed line only. The heating agent is the exhaust steam, a back pressure being kept in the auxiliary exhaust line for this purpose by means of a spring-relief valve at each condenser connection, opening toward the condenser.

BOILERS AND APPURTENANCES.

Main Boilers.—There are three main boilers, of the horizontal, double-ended, Scotch type, arranged abreast in one compartment. Each furnace has an independent combustion

chamber. The general particulars of the boilers are given below.

Donkey Boiler.—A donkey boiler of the vertical, cylindrical, fire-tube type, is located in the boiler hatch, above the main boilers. The general characteristics of the boiler are given below.

Boiler Data.

	Main (each).	Donkey.
Working pressure, pounds gage	200	200
Mean diameter, feet and inches	16–00	7–00
Length of shell, feet and inches	22–01	....
Height, external, feet and inches	....	11–00
Thickness of shell, inches	01 1/32	00 23/32
Furnaces, type	Morison corrugated	Cylindrical
number	8	1
diameter, inside, feet and inches	3–05	6–04
thickness, inch	00 17/32	5/8 (stayed)
Grates, length, feet and inches	5–06	circular
width, inches	41	6′ 3″ diameter.
Grate surface, square feet	150.33	30.68
Heating surface, square feet	6,545	1,046.54
Ratio grate surface to heating surface	1:43.54	1:34.11
Clear area through smoke pipe, square feet	71.72	4.91
to grate area	6.29:1	6.25:1
Tubes, material	charcoal iron, lap welded	
number, ordinary	708	196
stay	360	104
diameter, all, inches	02½	02
thickness, ordinary, B.W.G	12	12
stay, inches	5/16 and 7/32	¼
length between tube sheets, ft. and ins.	7–10⅛	6–03¾
Diameter, boiler stop valve, inches	08	03
safety valves, inches	04½ triple	02½
feed, stop and check valves, inches	03	01½
bottom-blow valves, inches	02½	01½
surface-blow valve, inches	01½	....

Uptakes and Smoke Pipes.—The main boilers are connected by suitable uptakes to one smoke pipe, 10 feet in diameter by 91 feet 1½ inches high above the lower grates. The uptakes and smoke pipes are double cased, with air space between casings. The smoke pipe is stayed by twelve wire-rope guys, arranged in two rows of six guys each.

On the front of the smoke pipe is a ladder, extending from the top of the boiler hatch to the top of the pipe, also a whistle and a siren located about 15 feet from the top of the pipe, and on the rear is a 12-inch escape pipe.

The donkey-boiler smoke pipe 30 inches in diameter, is led inside and to the top of the main smoke pipe.

FIRE-ROOM AUXILIARIES.

Forced-draft System.—The Howden closed ash pit, hot air, forced-draft system is installed for the main boilers. The air is supplied by two No. 9 Sturtevant, double-inlet, multivane fans, each driven by a vertical, single steam engine, with 5-inch steam cylinder by 4-inch stroke. One blower is located over each wing boiler. The air is drawn from the fire rooms and delivered to the boilers through ducts, connected to heater boxes in the uptakes, where it is heated before delivery to the ash pits.

Ash Ejectors.—Two, above-water discharge, hydraulic, ash ejectors are installed, one in each fireroom. The pump for the apparatus is described in Table I.

Ash Hoist.—In addition to the ash ejectors mentioned in preceding paragraph, the starboard ventilator in the after fire room is arranged for hoisting ashes in a bucket by means of a 4½-inch by 4½-inch double steam engine made by the Hyde Steam Windlass Company.

MAIN STEAM PIPING.

The main steam piping is of seamless-drawn steel tubing. It is 9 inches in diameter and leads aft from the boilers to the engines in two lines, port and starboard. Steam is supplied through an 8-inch connection from each of the outboard boilers, and two 8-inch branches from the center boiler. The mains have a 7-inch cross-connection in the engine room. Stop valves are fitted near the forward engine-room bulkhead, at the boilers and in the cross-connection.

AUXILIARY STEAM PIPING.

The auxiliary steam piping is in two distinct circuits as given below. It is of seamless-drawn steel where subjected to boiler pressure, and copper for the loop in engine room, which is under reduced pressure.

From the main steam pipes in the engine room, with stop valves at the mains, 4-inch branches, starboard and port, form a common loop around the engine room. From these pipes branches are taken to the various engine-room auxiliaries, distilling apparatus, refrigerating and dynamo plants, steering engine, and capstan.

The fire-room auxiliary steam line is supplied from the engine room by a 5-inch branch. There is also a 3-inch connection from the donkey boiler to this line. From this pipe there are branch connections to the blowers, ash-ejector pump, etc., a 5-inch branch to deck machinery forward, the latter being led to the main deck, where it is carried forward along the deck, starboard of the coaling hatches, with branches to the winches and windlass engine. The deck piping is lap welded galvanized steel.

AUXILIARY EXHAUST PIPING.

The auxiliary exhaust pipe is of wrought iron, that exposed to the weather being galvanized. A main, 6 inches in diameter, is led throughout the machinery space, with connections from the various auxiliaries as required. The main is connected to the main and auxiliary condensers, there being a spring-relief valve at each connection opening toward the condensers.

The deck exhaust pipe, 4½ inches in diameter, is led along the port side of the main deck just outboard of the coaling hatches, with connections from the coaling winches and windlass engine, and down the boiler hatch to the auxiliary exhaust line in the fireroom.

BOILER FEED SYSTEM.

The main and auxiliary feed pumps, each, have a 5-inch suction from the 7-inch feed-tank suction pipe. Each pump has a 4-inch discharge connection discharging into the main and the

auxiliary feed lines, which are cross-connected in the engine room. The main feed line is 5 inches in diameter and discharges via the feed-water heater to the boilers. The auxiliary feed line is 4 inches diameter, but does not connect to the heater. All feed connections at the boilers are 3 inches in diameter. The feed discharge pipes are steel and the suction pipes copper.

INTERIOR COMMUNICATION.

The customary engine and fire-room telegraphs, gongs, voice tubes, etc., are fitted for transmitting orders and signaling to the machinery compartments and other parts of the vessels.

EVAPORATING AND DISTILLING PLANT.

Two evaporators and two distillers are provided, having a combined capacity of 8,000 and 4,000 gallons, respectively, in twenty-four hours. The former are located in the after end of the engine room, and the latter in the engine hatch. They are of the Reilly multicoil type, and operate in single effect.

Steam for the evaporator is taken off the auxiliary line, and the distiller fresh water is discharged by gravity to the fresh-water tanks and to the fresh-water filling manifold.

The distilling plant pumps are given in Table I.

ELECTRIC PLANT.

The dynamos are located on the 1st platform, port of the engine hatch. The installation consists of two horizontal, compound-wound, multipolar, direct-current, 25-kilowatt, Western Electric generators, each driven by a B. F. Sturtevant turbine. Each generator will deliver at normal load 200 ampères of current at 125 volts, when running 3,600 revolutions per minute.

REFRIGERATING PLANT.

A Brunswick ammonia compressor, of 2 tons' capacity, direct connected to a 5½ by 7-inch Wach's steam engine, is located on the 1st platform, port of the engine hatch, together with condenser, ammonia receiver and all appurtenances. The con-

denser circulating water is supplied by the distiller circulating pump in the engine room. The brine circulating pump and its connections are given in Table I.

The refrigerating rooms are located on the 2d platform just below and abaft the ice-machinery room.

ENGINEER'S WORKSHOP.

A spacious and complete workshop is provided on the 2d deck, off the engine hatch, starboard side. Its equipment includes the following machine tools, driven through shafting and belting by a 7½ H.P. 5-inch by 5-inch American Blower Company's vertical single engine:

1 16-inch swing by 2 feet 10-inch between centers engine lathe, Monarch Machine Company;
1 15-inch pillar shaper, Hendey-Norton;
1 22-inch swing upright drill, Barnes;
1 No. 4 Ransan grinder.

TRIALS.

The contracts required:

(*a*) A progressive trial over the measured-mile course at the Delaware Breakwater for standardizing the screws, extending from maximum speed (at least 14 knots) down to a speed of 8 knots; fourteen runs to be made over the course in order to adequately cover the range of speed desired.

(*b*) A full-speed and coal-consumption trial of twenty-four hours' duration in the open sea in deep water, at the highest speed attainable, which shall not be less than an average of 14 knots, determined from the official standardization curve of r.p.m. and speed. During the trial the air pressure in the ashpits shall not exceed an average of 1¼ inches of water, and the steam pressure at the H.P. valve chest shall not exceed 195 pounds above the atmosphere.

(*c*) Complete trials of the fuel-oil handling appliances and other apparatus, to demonstrate whether or not they fulfill the guarantees in the specifications.

Coal Consumption Guarantee.—The contractors guaranteed

that the coal consumption for all purposes on trial (*b*) shall not exceed 850 pounds per knot run, reduced to 14 knots speed in proportion to the fourth power of the revolutions.

PANAMA COLLIER ULYSSES
TABLE II-STANDARDIZATION TRIAL DATA-APRIL 14, 1915

No. of Run.	Time on Course		Speed in Knots.	R.P.M.			I.H.P.		
	Mins.	Secs.		Star. Engine.	Port Engine.	Mean.	Star. Engine.	Port Engine.	Total.
2	5	16.7	11.37	86.19	86.52	86.36	2397	2392	4789
3	4	15.0	14.12	83.84	84.35	84.20	2408	—	—
4	4	58.9	12.04	86.06	86.09	86.08	2398	—	—
Mean of Group			12.91			85.21			—
5	3	49.5	15.69	97.73	96.70	97.22	3937	3700	7637
6	4	14.9	14.12	99.51	98.46	98.99	—	4442	—
7	3	50.2	15.64	99.34	98.27	98.81	4146	4593	8739
8	4	2.5	14.05	99.68	98.09	99.29	4127	4479	8606
9	4	0.7	14.96	99.37	98.26	98.82	4065	4375	8440
Mean of Group			14.99			98.76			8595*
11	5	48.1	10.34	70.10	74.23	72.17	1615	1732	3367
12	4	55.7	12.17	70.55	71.60	71.08	1361	1683	3044
13	6	18.9	9.50	71.06	71.30	71.18	1414	1608	3022
Mean of Group			11.05			71.38			3119
14	6	23.2	9.35	51.16	47.47	49.32	599	430	1029
15	8	59.4	6.67	53.34	54.06	53.70	593	761	1354
16	6	8.5	9.77	56.39	56.65	56.52	726	975	1701
Mean of Group			8.12			53.31			1360

* Average of 7th, 8th & 9th Runs.

The standardization trial (*c*) of the *Ulysses* was run April 14, 1915, and that of the *Achilles* June 8, 1915. The mean displacement on the five high-speed runs was 19,375 tons and

PANAMA COLLIER ACHILLES
TABLE III-STANDARDIZATION TRIAL DATA-JUNE 8, 1915.

No. of Run.	Time on Course.		Speed in Knots.	R.P.M.			I.H.P.		
	Mins.	Secs.		Star. Engine.	Port Engine.	Mean.	Star. Engine.	Port Engine.	Total.
2	4	31.1	13.28	85.51	86.02	85.77	2327	2758	5085
3	4	38.5	12.93	86.20	85.76	85.98	2328	2659	4982
4	4	11.4	14.32	88.26	87.49	87.88	2612	2766	5378
Mean of Group			13.37			86.40			5107
5	4	16.0	14.06	101.52	98.95	100.24	3942	4216	8158
6	3	36.5	16.63	101.58	99.22	100.40	3795	4119	7914
7	4	22.7	13.70	101.28	98.73	100.01	4185	3999	8194
8	3	34.8	16.76	101.69	99.11	100.40	4123	4049	8172
9	4	25.5	13.56	100.56	97.76	99.16	3983	3981	7964
Mean of Group			15.23			100.13			8086
11	6	13.8	9.63	70.21	72.04	71.13	1295	1632	2927
12	4	56.3	12.07	69.86	71.55	70.71	1224	1569	2793
13	6	1.0	9.37	69.21	71.51	70.36	1215	1510	2725
Mean of Group			10.94			70.73			2810
14	6	40.4	8.99	54.31	55.08	55.70	704	706	1409
15	7	25.1	8.09	54.58	53.15	53.87	670	644	1314
16	7	25.0	8.09	55.90	54.42	55.16	689	670	1359
Mean of Group			8.32			54.66			1349

TABLE IX – TRIAL

	PANAMA CANAL COLLIERS			
	ULYSSES	ACHILLES	CYCLOPS	VULCA
DATE OF TRIAL	APRIL 14 & 15, 1915	JUNE 8 & 9, 1915	Oct. 26, 27 & 28, 1910	SEPT. 15 & 1
DURATION, HOURS	24	24	48	24
SPEED IN KNOTS	14.605	14.201	14.61	12.82
DRAUGHT, MEAN ON TRIAL, FEET AND INCHES	27-5¾	27-8½	27-3½	24-8
DISPLACEMENT, CORRESPONDING, TONS	19,336	19,322	19,095	12,26
PRESSURES (AVERAGE):	ST'BD. | PORT	ST'BD. | PORT	ST'BD. | PORT	ST'BD. |
MAIN STEAM, AT BOILERS, POUNDS GAUGE	200.0	194.5	192	191
ENGINES, " "	194.1 | 194.9	194.6 | 196	— | —	182.6 |
1ST RECR. " ABSOLUTE	82.3 | 82.9	70.6 | 75	— | 67.7	70.8
2ND " " "	30.1 | 29.7	24.8 | 24.3	24.6 | 24	25.45
VACUUM, MAIN CONDENSER, INCHES OF MERCURY	25.7 | 25.9	25.9 | 26	26.4 | 27.7	26.8 |
BAROMETER, INCHES OF MERCURY	30.37	29.83	—	—
MAIN FEED, AT PUMPS, POUNDS GAUGE	230.6	212.2	—	—
AUXILIARY EXHAUST, " "	11.3	5.61	12.5	—
AIR PRESSURE IN ASH PITS, INCHES OF WATER	.6	.258	0.41	—
MEAN EFFECTIVE PRESSURES, POUNDS (AVERAGE):				
H.P. CYLINDER	87.5 | 85.7	82 | 85.25	85.90 | 90.12	84.3 |
I.P. "	29.6 | 32.4	27.02 | 29.32	30.79 | 31.77	27.5 |
L.P. "	13.1 | 14.9	10.08 | 12	12.38 | 18.49	11.45 |
REFERRED PRESSURE	34.93 | 37.57	33.48 | 30.32	34.27 | 33.26	33.53 |
REVOLUTIONS OR DOUBLE STROKES PER MINUTE (AVERAGE):				
STARB'D. ENGINE	96.62	93.02	92.109	92.5
PORT ENGINE	96.3	92.58	92.336	91.7
MEAN	96.46	92.80	92.223	92.1
MAIN CIRCULATING PUMPS	102.2 | 100.4	131.42 | 132.71	159 | 156	199 |
FEED PUMPS	11.5	10.75	22.8	12.5
FORCED DRAFT BLOWERS	363.5 | 389.8	370	283 | 267	485.6
INDICATED HORSEPOWER (AVERAGE):				
H.P. CYLINDER	1185 | 1144	1062 | 1098	1106 | 1160	631 |
I.P. "	1138 | 1245	1002 | 1078	1127 | 1168	596
L.P. "	1184 | 1575	1028 | 1220	1244 | 1077	652
TOTAL	3707 | 3964	3092 | 3396	3477 | 3400	1879 |
BOTH ENGINES	7671	6488	6877	3736
TEMPERATURES, DEGREES F. (AVERAGE):				
MAIN INJECTION	44.9	53.08	—	67.2
OVERBOARD DISCHARGE	119.7 | 118.2	118.6 | 116.13	—	112.2 |
FEED TANK	125.6	139.3	—	—
FEED WATER	192.4	202.54	—	208.8
ENGINE ROOM	70.5	75.79	70.90	—
FIRE ROOMS	76.5	75.0	79.90	86.0
OUTSIDE AIR	52.3	65.07	58	—
SMOKE PIPE	739.2	661.04	397	520
COAL CONSUMPTION DATA:				
KIND	NEW RIVER.	NEW RIVER	—	POCAHO
QUALITY	EXCELLENT	EXCELLENT	—	RUN OF M
B.T.U. PER POUND	13,577	14,897	—	—
POUNDS PER KNOT RUN	791.184*	678.034*	681.314	492.4
HOUR	11,564	9,683	9,954	6,81
PER I.H.P. MAIN ENGINES	1.507	1.492	1.447	1.6
SQ. FT. OF GRATE SURFACE	25.641	21.471	22.12	26.9
HEATING "	0.589	0.493	0.514	0.6
MISCELLANEOUS DATA:				
SLIP OF PROPELLERS, PERCENT, MEAN	8.85 | 9.32	8.77 | 7.88	10.7 | 10.95	— |
STARB'D. & PORT	9.59	8.33	10.825	—
GRATE SURFACE, SQ. FT.	451	451	450	234.
HEATING " " "	19,635	19,635	19,379	10,2
I.H.P. PER SQ. FT. OF GRATE	17.089	14.385	15.282	15.5
SQ. FT. OF HEATING SURFACE PER I.H.P.*	2.56	2.028	2.818	2.7
COOLING " (MAIN COND.), PER I.H.P.*	1.382	1.634	1.455	1.4
KNOTS PER TON OF COAL	2.829	3.304	3.288	4.5
MAIN ENGINES, TYPE	3-CYL., 3-EXP., VERT.	3-CYL., 3-EXP., VERT.	3-CYL., 3-EXP., VERT.	3-CYL., 3-E
DIAMETER OF CYLINDERS, INCHES	27½ x 46 x 76	27½ x 46 x 76	27½ x 46 x 76	22 x 87
STROKE, FEET	4	4	4	3

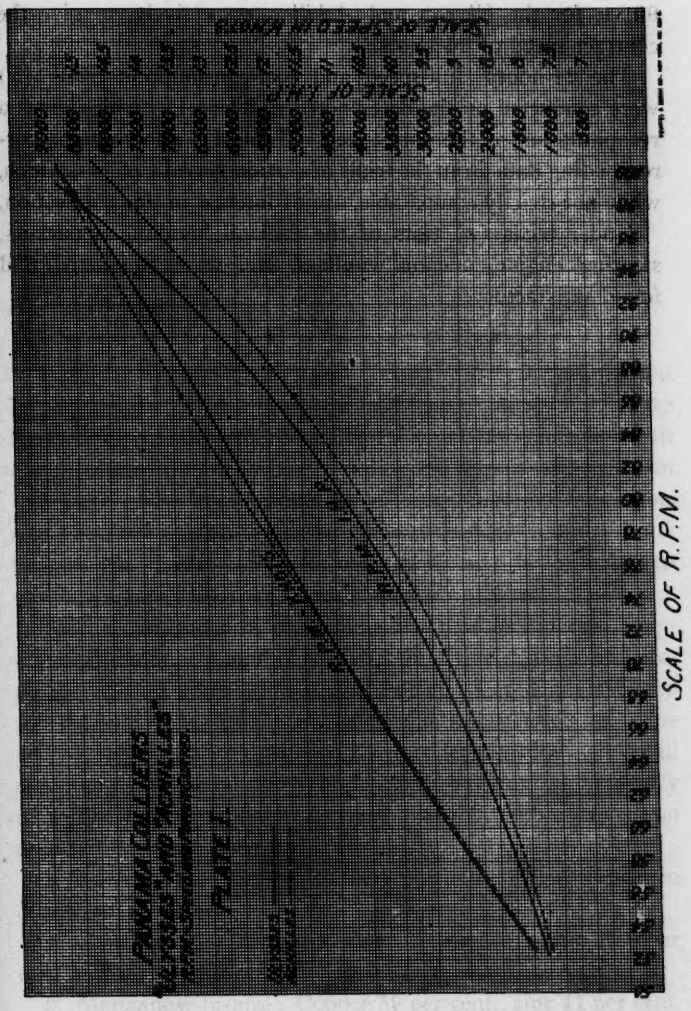
* I.H.P. MAIN ENGINES ONLY. ° AT 14 KNOTS. – GUARANTEE 850 LBS: ULYSSES 703.422 LBS., ACHILL
LESS THAN GUARANTEE: " 146.578 " "

- TRIAL DATA

U.S. FLEET COLLIERS.

	VULCAN	MARS	HECTOR	PROTEUS	NEREUS	ORION	JASON
	SEPT. 15 & 16, 1909.	AUG. 18 & 19, 1909.	OCT. 14 & 15, 1905.	JUNE 27 & 28, 1913.	SEPT. 3 & 4, 1913.	JULY 10, 11 & 12, 1912.	JUNE 18 & 19, 1913.
	24	24	24	18	18	48	24
	12.82	12.65	12.87	14.675	14.575	14.467	14.322
	24-8½	24-8¾	24-11¼	27-2¾	27-3¼	27-0¾	27-0¼
	12,264	11,292	11,162	19,050	18,830	18,800	18,862
	ST'B'D. | PORT	ST'B'D. | PORT.	ST'B'D. | PORT.	ST'B'D. | PORT.	ST'B'D | PORT	ST'B'D. | PORT	ST'B'D. | PORT
	191	196	196	202.3	197.5	195	199.6
	182.6 | 182.6	179	— | —	189.5	192.3	192	194.9
	70.8 | 76.0	77.6 | 80	85 | 84.45	72.6 | 73.2	85.3 | 79.7	—	82.1 | 84.1
	25.45 | 26.66	26.7 | 26.1	28.97 | 29.47	23.2 | 23.4	22.8 | 23.72	—	25.3 | 26.0
	26.8 | 25.65	27.18 | 26.85	25.64 | 26.05	26.3 | 24.02	24.44 | 26.52	—	25.84 | 26.14
	—	—	—	30.02	30.07	—	30.18
	—	—	—	—	—	—	—
	—	—	—	—	—	—	—
	—	—	—	—	—	—	—
		2.0	2.0	0.89	0.985	1.0	1.334
	86.3 | 87.5	87.3 | 84.5	86.5 | 80.33	37.2 | 34.3	81.6 | 86.1	—	85.5 | 82.3
	27.5 | 27.3	28.8 | 30.7	31.35 | 30.33	30.4 | 33.75	36.7 | 37.1	—	33.9 | 34.7
	11.65 | 11.35	12.45 | 11.1	12.45 | 12.58	10.98 | 12.2	9.8 | 11.1	—	9.7 | 10.7
	33.53 | 33.41	32.87 | 31.28	34.17 | 34.79	33.14 | 35.16	32.24 | 34.22	—	32.48 | 33.39
	32.58	31.99	92.78	100.86	98.82	94.76	96.04
	31.76	94.69	94.57	102.14	98.27	95.24	94.35
	32.18	93.34	93.675	101.5	99.07	95.0	95.2
	199 | 202	158 | 203	206.6 | 209.4	207 | 205	140.1 | 140.2	—	121.87 | 120.37
	12.5	7.59	9.48	11.5	13.85	—	11.35
	485.0	522.0	494.0	295 | 263	335.3 | 325.1	—	485.8 | 484.48
	631 | 633	645 | 627	619 | 586	1235 | 1210	1020 | 1080	— | —	1091 | 1055
	596 | 582	632 | 690	679 | 653	1100 | 1238	1308 | 1326	— | —	1284 | 1323
	452 | 632	381 | 643	682 | 702	1138 | 1234	1017 | 1152	— | —	1002 | 1123
	1879 | 1857	1858 | 1960	1980 | 1941	3473 | 3734	3345 | 3568	3393 | 3550	3377 | 3501
	3736	3818	3921	7207	6904	6943	6878
	67.2	—	65.62	75.5	75.3	—	63.1
	112.2 | 110.5	—	116.38 | 111.93	115.0 | 106.2	103.9 | 107.2	—	108.3 | 110.8
	—	—	—	124.3	119.9	—	113.5
	208.5	—	202.08	133.3	170.1	—	174.8
	—	—	86.2	100.9	88.4	—	87
	86.0	—	—	100.35	100.5	—	94.88
	—	—	15.45	80	74.0	—	66.4
	520	—	550	—	—	—	—
	POCAHONTAS RUN OF MINE	POCAHONTAS RUN OF MINE	POCAHONTAS RUN OF MINE	NEW RIVER PICKED.	NEW RIVER RUN OF MINE	POCAHONTAS FAIR	POCAHONTAS POOR
	492.434	561.502	505.944	15,163	14,841	14,388	12,688
	6,813	7,103	6,511.5	746.494	727.199	724.131	914.305
	1.69	1.66	1.66	10,954.8	10,538.93	10,476	13,094.67
	26.9	30.26	27.746	1.52	1.535	1.509	1.304
	0.619	0.696	0.638	25.47	24.649	23.809	29.761
				0.592	0.573	0.554	0.692
	— | —	— | —	— | —	10.19 | 10.64	8.97 | 9.38	14.056 | 14.498	16.05 | 14.55
	—	—	—	10.42	9.18	14.272	15.3
	234.68	234.68	234.68	430	430	440	440
	10,200	10,200	10,200	18,492	18,492	18,921	18,921
	15.92	16.28	16.708	16.76	16.056	15.78	15.632
	2.73	2.67	2.601	2.55	2.676	2.725	2.751
	1.65	1.62	1.579	1.25	1.304	1.586	1.55
	4.549	3.989	4.427	3.001	3.08	3.093	2.45
VERT. 76	3-CYL., 3-EXP. VERT. 22 x 37½ x 60 3½	3-CYL., 3-EXP. VERT. 22 x 37½ x 60 3½	3-CYL., 3-EXP. VERT. 22 x 37½ x 60 3½	3-CYL., 3-EXP. VERT. 26 x 43½ x 74 4	3-CYL., 3-EXP. VERT. 26 x 43½ x 74 4	3-CYL., 3-EXP. VERT. 27 x 46 x 76 4	3-CYL., 3-EXP. VERT. 27 x 46 x 76 4

LBS., ACHILLES 633.92 LBS.
" , " 216.08 "



19,293 tons, respectively. The data taken on these trials is given in Tables II and III, from which the curves, Plate I, were plotted. From the official r.p.m.-speed curves it was found to require a mean r.p.m. of both shafts of 92.5 and

90.81, for the *Ulysses* and *Achilles,* respectively, to give the contract speed of 14 knots.

The 24-hours' full-speed and coal-consumption trials (*b*) were conducted on the dates noted in Table IV, which gives a recapitulation of the data taken. Table IV also contains corresponding data from the trials of certain Naval Colliers, which, while not strictly comparable, are of interest in this connection.

Under trials (*c*) tests of the fuel oil handling apparatus, steering engine, anchor windlass, etc. were conducted and found satisfactory.

MANGANESE-BRONZE.

A DESCRIPTION OF ITS MANUFACTURE FROM VARIOUS SCRAP MATERIALS.

By Lieutenant J. B. Rhodes, U. S. Navy, Member.

1. At the Washington Navy Yard the accumulation of a large quantity of miscellaneous non-ferrous scrap has led to the careful study of the metallurgical problems connected with the successful use of such materials. It is proposed to deal in this paper with the production of manganese-bronze ingots alone and to describe the materials used and the foundry practice, so that the experience gained here may be of value to others who are confronted with a similar problem.

2. The accumulation consisted chiefly of skimmings, turnings and trimmings, and obsolete or defective castings of compositions so doubtful that it was not considered advisable to use the materials directly in the production of castings. The yellow-metal scrap only is worth considering, although small amounts of red-metal scrap can be used to obtain the necessary tin. The following materials were available with composition approximately as shown:

1. Naval Brass: Copper 62 per cent., zinc 37 per cent., tin 1 per cent.

2. Cartridge-case Metal: Copper 68 per cent., zinc 31.6 per cent., nickel 0.4 per cent.

3. Manganese-bronze: Copper 59 per cent., zinc 41 per cent.

4. Commercial brass can be used in small quantities but should be avoided, as the lead content is too high.

3. Of these materials (1) naval brass and (2) cartridge-case metal can be and have been used in the manufacture of

cast naval brass, but the demand for cast naval brass has not been great enough to warrant holding scrap for use in that alloy alone, so it has been necessary to work out an economical and practical method for manufacturing manganese-bronze ingots.

4. The results of experiments during about six (6) months have shown that it is practicable to make high-grade ingots in an oil-fired Rockwell furnace of about two (2) tons' capacity. This has been accomplished in spite of the well-known prejudice against open-flame furnaces in the manufacture of non-ferrous alloys. Oxidation has been reduced to a very small amount by using wood scraps from pattern shop and salt. The bath is protected by the molten salt, and the wood insures a reducing rather than an oxidizing atmosphere in the furnace. The zinc losses are lower than is the case when no covering is used.

5. Before undertaking the manufacture of manganese-bronze itself a special hardener is made. This hardener is really the secret of the whole process, and although it can be made in any desired proportions, it has been found that the following is most satisfactory: 100 pounds copper, 25 pounds mild steel, 25 pounds (80 per cent.) ferro-manganese. The ferro-manganese and mild steel are melted and the copper (usually copper wire or other scrap) added as fast as the mixture will take it. Pots should be well stirred in the furnace. The alloy is best made using pots containing about 250 pounds each, and pouring these into a ladle for casting. Great care should be taken to skim the pots before pouring into the ladle. The hardener can be cast into ingots in green-sand open molds. After carefully skimming, both in the pot and in the ladle, it will be found that practically all of the carbon has been eliminated, as it separates from the alloy, floats on the top and is removed by the skimming. The resultant alloy will be quite clean and can be readily broken into pieces of any size. The alloy has a characteristic blue-gray color.

6. This hardener has proved most satisfactory as a means of

introducing the desired percentages of iron and manganese. Aluminum and tin are added at the end of the heat, as needed, to make up the desired percentages of these constituents.

7. In determining the proper amount of scrap for a charge the approximate analysis of scrap on hand must be known. It is necessary to consider the scrap as so many pounds of copper, tin and zinc, and sufficient accuracy will be found if we work out the mixture to contain 57 per cent. copper and add aluminum and tin as may be necessary. Suppose there is on hand a stock of scrap condenser tube containing, approximately, 70 per cent. copper, 29 per cent. zinc and 1 per cent. tin. In order to bring the copper content to 57 per cent. it will be necessary to use only about 78 pounds of scrap per 100 pounds of manganese-bronze. Zinc is added to reduce the percentage of copper.

8. The composition desired is as follows: Copper 57 per cent., zinc 40 per cent., iron 1.00 per cent., manganese, 0.75 per cent., aluminum 0.75 per cent., tin 0.50 per cent.

To obtain manganese 0.75 per cent., about 5 pounds of hardener should be used for every 100 pounds; this gives 2½ pounds copper, so that only enough scrap (condenser tube) should be added to bring copper content to 57 per cent., *i. e.*, 54.5 pounds of copper, which will be obtained from 78 pounds of scrap. This amount of scrap will carry 0.78 per cent. tin. In addition to these, one (1) pound of aluminum should be added for every 100 pounds of charge as computed. Aluminum, manganese and tin will be burned out to a slight extent.

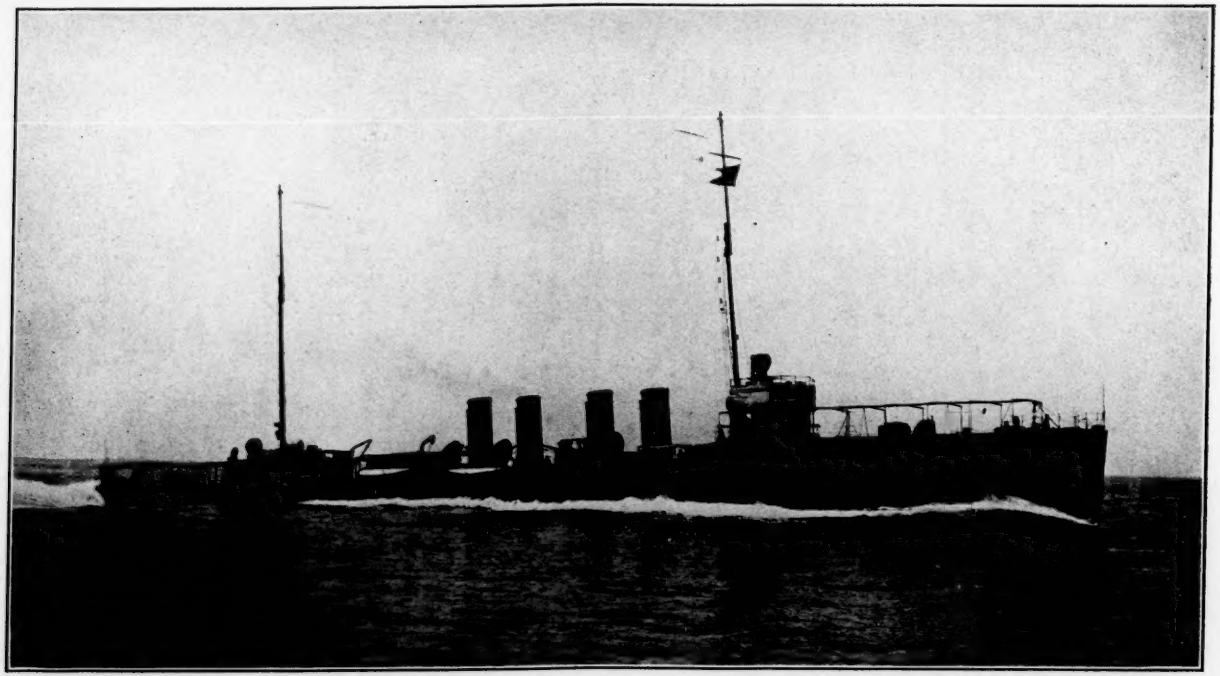
We now have 78 pounds condenser tube, 5 pounds hardener, 1 pound aluminum. To this should be added 16 pounds zinc to bring total to 100 pounds. This gives a zinc content of 38 per cent., assuming that there are no losses. About 5 to 8 pounds more should be added to make up for losses, which actually do occur, and the desired composition will finally be obtained.

9. After analysis of the heat the amount of zinc necessary to bring zinc up to 41 per cent. can be calculated, and this

amount should be added when remelting for pouring into castings. The best bronze, showing the highest tensile strength, is a bronze containing 41 per cent. zinc. If zinc drops to even 38 per cent., tensile strength is reduced and elongation is increased and a soft bronze obtained.

10. In melting in the oil furnace the most difficult scrap to melt should be charged first, although all but finals may be charged at once. As soon as melted the hardener should be added. In about half an hour charge the remaining scrap (if charge is not made all at same time) and continue the melt. After the heat is well up add zinc, then tin (if necessary) and finally aluminum; stir well and tap. Small ladles are used for pouring the ingots. Ingots are numbered to show the heat and turned into the store awaiting analysis. The cost of the method is high, on account of the labor in pouring and marking ingots, but, counting in furnace loss, labor, fuel and upkeep of furnace it is less than two cents per pound, so that scrap worth 7½ cents per pound can be converted into manganese-bronze to cost not over 10 cents per pound.

11. One of our heats gave 82,000 pounds' tensile strength and 28 per cent. elongation. Quite frequently 75,000 pounds' tensile strength and 20 per cent. elongation are obtained in sand castings. If high pouring temperatures are avoided and the metal is poured when it ceases to give off zinc fumes in large volume, it will be found that excellent values are obtained so long as the zinc content is kept up at or about 41 per cent.



Photograph taken by the NEW YORK SHIPBUILDING COMPANY.

U. S. T. B. D. "ERICSSON," ON TRIAL TRIP.

ERICSSON.

By W. H. A. LANGE, ASSOCIATE.

The *Ericsson*, Torpedo Boat Destroyer No. 56, is one of six destroyers of the same class authorized by an act of Congress approved August 22, 1912. These vessels were designated as Torpedo Boat Destroyers Nos. 51 to 56, inclusive.

The contract for the *Ericsson*, signed December 16, 1912, was awarded to the New York Shipbuilding Company, Camden, N. J., for $873,500, the vessel to be delivered twenty-four months after date of contract. Contract speed, 29 knots at about 1,090 tons displacement, main engines developing about 17,000 shaft horsepower.

The *Ericsson* is a twin-screw vessel equipped with Parsons turbines (main engines) in combination with a single reciprocating engine for cruising speeds.

PRINCIPAL HULL DATA.

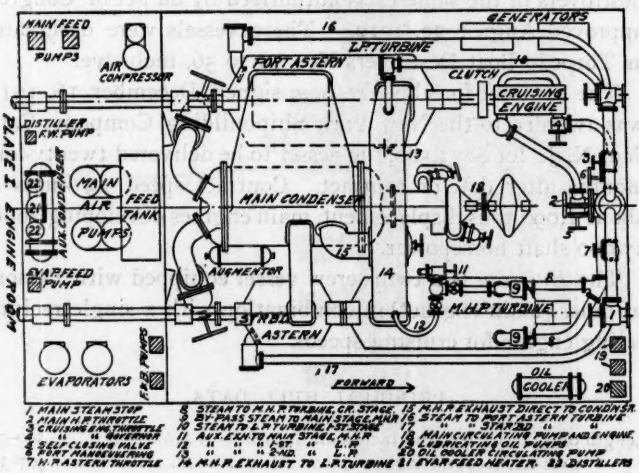
Length on L.W.L., feet and inches	300–7
over all, feet and inches	305–3
Breadth on L.W.L., feet and inches	30–6
over guards, feet and inches	31–1
Draught, mean, feet and inches	9–9
Displacement, normal, tons	1,090
Tons per inch immersion at normal draught	14.50
Area immersed, midship section, square feet	204
Block coefficient	.427
Fuel-oil tanks, capacity, tons	309
Reserve feed-water tanks, capacity, tons	18
Additional, in cofferdam, tons	18
Fresh-water tanks, capacity, tons	17.5

The arrangement of machinery spaces, store rooms, officers' and crew's quarters, fuel-oil stowage tanks, reserve feed and fresh-water tanks and other minor compartments is, in gen-

eral, the same for all destroyers of this class. The propellers are located at the same frame space as those on the *Nicholson*, described in the previous issue of this Journal, but 10 inches farther out from the center line of the vessel.

MACHINERY.

The general arrangement of propelling engines and auxiliary machinery in engine rooms is shown on Plate I.



A vertical, inverted, direct-acting compound reciprocating engine, $\frac{16 \times 24}{18}$, with cranks at 180 degrees, is arranged forward of the low-pressure and astern turbine, on the port shaft; the main high-pressure ahead turbine and an independent astern turbine are mounted on the starboard shaft. The main engines are designed to develop 17,000 shaft horsepower at about 600 revolutions per minute when propelling the vessel at the contract speed of 29 knots.

A disconnecting clutch, of the Metten hydraulic type, is interposed between the cruising engine and the L.P. turbine for cruising speeds up to 15½ or 16 knots. When speeds

greater than this are desired, the clutch is released without stopping the engine.

This clutch is operated with oil at a pressure of about 70 pounds per square inch. It is fully described by Mr. J. F. Metten, the inventor, in the JOURNAL OF THE AMERICAN SOCIETY OF NAVAL ENGINEERS, Vol. XXVI, No. 1, February, 1914.

A significant feature in connection with the arrangement of valves and piping to the reciprocating engine is, that, should the pressure of oil on the clutch diaphragm suddenly drop, the throttle of the reciprocating engine automatically closes instantly, thus preventing this engine from racing. Steam cannot be admitted to the astern turbine on the same shaft while the reciprocating engine is in use; neither can the throttle to reciprocating engine be opened while the port astern turbine throttle is open. By a slight movement of the handwheel on cruising-engine throttle, through an arc of 30 degrees, the astern throttle is locked in closed position and oil cock opened, applying full pressure to the clutch, which engages instantly, and to the governor valve of reciprocating engine, placing it in position for immediate action in case of emergency. The clutch is not again released until at the instant the throttle valve is closed. Steam can be admitted to the L.P. ahead turbine on the same shaft while the cruising engine is in use.

Metten clutch:	
Outside diameter, feet and inches	3–10½
Over all, inches	9
Disc, diameter, feet and inches	3–7½
Thickness, at center, inch	0⅜
periphery	0 5/16
Intermediate shaft:	
Outside diameter, inches	8
Diameter hole through shaft, inches	5
at journal, inches	8
Length, feet and inches	2–8½

Ship coupling, intermediate shaft to L.P. rotor shaft, 8 steel pins 1¼ inches diameter on 12-inch pitch circle, fitted in steel bushings; allowable fore-and-aft movement, ¼-inch.

Line shaft:	
Two sections, outside diameter, inches	8¾
Diameter hole through shaft, inches	5
at journals, inches	8¾
Total length of both sections, feet and inches, about	34–7
Stern-tube shafts:	
Outside diameter, inches	8½
Diameter hole through shaft, inches	5
Composition casings at bearings, thickness, inch	0 7/16
outside diameter, inches	9⅜
between bearings, thickness, inch	0¼
Length of shafts, feet and inches	27–6½
Propeller shafts:	
Outside diameter, inches	8⅞
Diameter hole through shaft, inches	5
reduced at ends to diameter, inches	2⅝
Composition casings at bearings, thickness, inch	0⅜
outside diameter, inches	9⅝
Length of shafts, feet and inches	21–0 5/16
Three line-shaft bearings, length, inches	12
Stern-tube forward bearing, length, feet and inches	2–4
after bearing, length, feet and inches	3–6
Propeller-shaft bearings, length, feet and inches	3–6
Propellers:	
Diameter, inches	91½
Pitch, inches	78
Projected area, one blade, square inches	1,341
three blades, square inches	4,024
Projected area ÷ disc area	.612
Developed area, one blade, square inches	1,500
three blades, square inches	4,500
Developed area ÷ disc area	.684
Specified r.p.m.	600
Specified shaft horsepower	17,000
Main condenser, tubes curved in a vertical plane and expanded in tube sheets at both ends:	
Cooling surface, square feet	10,800
Tubes, number	5,471
diameter, outside, inch	⅝
thickness, inch	.049
Length between tube sheets, feet and inches	12–0¾
Wet suction from the shell, diameter, inches	15
Dry suction from the shell, diameter, inches	15
Circulating water connections, injection, diameter, inches	30
Circulating water connections, outboard delivery, number and diameter	2 of 21

Main circulating pump, a Worthington 30-inch Bi-rotor centrifugal, volute, runners, diameter, inches	27½
Driven by a Terry steam turbine, type C.M.B. rotor, diam., ins.,	36
Suction connections, number and diameter, inches	2 of 21
Discharge connection, diameter, inches	30
Suction connection from bilge, diameter, inches	7
Discharge connection to augmentor, diameter, inches	5½
Augmentor condenser, straight tubes:	
Cooling surface, square feet	320
Tubes, number	392
diameter, outside, inch	0⅝
thickness, inch	.049
Length between tube sheets, feet	5
Circulating water connections, diameter, inches	5½
Vapor inlet, diameter, inches	13
Discharge outlet, to water seal, diameter, inches	12
Auxiliary condenser, tubes curved in a vertical plane and expanded in tube sheets at both ends:	
Cooling surface, square feet	300
Tubes, number	316
diameter, outside, inch	0⅝
thickness, inch	.049
Length, between tube sheets, feet and inches	5–10
Circulating water connections, diameter, inches	4
Auxiliary exhaust nozzle, diameter, inches	7
Air-pump suction, nozzle diameter, inches	4
Feed and filter tank:	
Filter space capacity, gallons	285
Feed tank proper, capacity, gallons	510
Total capacity, gallons	795
Feed-water heaters, two, one in each fireroom, type, Schutte-Koerting, spirally corrugated tubes, $\frac{5}{16}$-inch film.	
Tubes, inner, inside diameter, inches	1⅜
thickness, inch	.083
outer, inside diameter, inch	$1\frac{13}{16}$
thickness, inch	.095
Heating surface, each heater, square feet	229
Lubricating oil supply, tanks, capacity, gallons	500
drain tank, capacity, gallons	200
settling tank, capacity, gallons	200
Evaporators, two, Reilly marine type:	
Heating surface, each, square feet	61.5
total, square feet	123
Specified evaporation, in 24 hours, gallons	3,750
Distillers, two, Reilly marine type:	
Cooling surface, each, square feet	18.45
total, square feet	36.9
Specified capacity in 24 hours, gallons	2,500

Evaporator feed-water heater, one, Navy type U tubes, heating surface, square feet 16.49

Oil coolor, one, Schutte-Koerting spirally-corrugated tube type, cooling surface, square feet 131.76

Reheater, in exhaust from cruising engine to H.P. turbine, straight tubes, heating surface, square feet 113.11

Fuel-oil heaters, four, two in each boiler room; type, Schutte-Koerting spirally corrugated tubes:

Heating surface, each, square feet 11.08
total, square feet 44.32

Air compressor, one Westinghouse, 11 × 11 × 12, in after boiler room, for pneumatic tools and cleaning tubes.

Air compressor, one Ingersoll-Rand, in auxiliary machinery room for torpedoes. Capacity, 20 cubic feet at 2,500 pounds pressure.

Torsion meters, one on each shaft, in auxiliary machinery room; type, Gary-Cummings.

Generators, two (Westinghouse, steam-turbine driven), 25 kw., 125 volt D. C., in engine room.

Forced-draft blowers, two in each boiler room:

Type, Keith fans, diameter, inches 32½
Terry steam turbines, rotor, diameter, inches 24

Boilers, four Thornycroft, water-tube, oil burning:

Heating surface, each boiler, square feet 5,984
total, square feet 23,936
Working pressure, gage 265
Tubes, outside diameter, inches 1½
thickness, millimeters 109
number in each boiler 2,160
outside diameter, inches 1⅝
thickness, millimeters 120
number in each boiler 170
downcomers, two, diameter each, inches .....
Steam drum, inside diameter, inches 42
Water drums, two, inside diameter, inches 19
Length, over all, including lagging, feet and inches 14–3½
Width, over all, including lagging, feet and inches 16–2
Height, over all, including lagging, feet and inches 13–6
Furnace volume, cubic feet 620
Area through uptakes, square feet 18.5
smoke pipe, square feet 18.5
$\frac{\text{Heating surface}}{\text{Furnace volume}}$, ratio 9.65
$\frac{\text{Smoke pipe area}}{\text{Furnace volume}}$, ratio ..... .03

Smoke pipes, 4, each 20 feet in height above deck line.

Oil Burners, Schutte-Koerting, 11 to each boiler.

No.	Purpose.	Pumps. Size, inches.	Type.
2	Main air.	14 × 28 × 28 × 18	Twin, vertical, single acting.
1	Main circulating.	30 inch.	Centrifugal.
2	Main feed.	15 × 10 × 16	Vertical, simplex, double acting.
2	Auxiliary feed.	15 × 10 × 16	do.
3	Fire and bilge.	7 × 7 × 12	do.
1	Oil cooler.	7 × 7 × 12	do.
1	Evaporator feed.	4½ × 6 × 6	do.
1	Distilller fresh water.	3½ × 4 × 4	do.
1	Aux. condenser air and circulating.	6 × 8 × 8 × 7	Horizontal combined air and water.
2	Lubricating oil.	6 × 5½ × 8	Vertical, simplex, double acting.
2	Fuel-oil booster.	6 × 5½ × 8	do.
4	Fuel-oil service.	6 × 3½ × 8	Vertical, duplex, double acting.
2	Air compressor.	11 × 11 × 12	Westinghouse.

The main circulating pump is of the Worthington bi-rotor volute type, direct connected to a Terry steam turbine. All other pumps are of the Blake type.

Low Cruising.—Steam is admitted to the reciprocating engine, from which it exhausts, through the re-heater, to the cruising stage of the M.H.P. turbine, thence to the 1st stage of the low-pressure turbine and thence to the condenser. Clutch connected. Auxiliary exhaust steam is admitted to the main stage of the M.H.P. turbine.

High Cruising.—Clutch to reciprocating engine disconnected. Steam is admitted to the cruising stage of the M.H.P. turbine, thence to the 1st stage of the low-pressure turbine and thence to the condenser. Auxiliary exhaust steam is admitted to the 1st stage of the low-pressure turbine.

Full Speed Ahead.—Steam is admitted to the cruising stage of the M.H.P. turbine, with by-pass open to the main stage, thence to the first stage of the low-pressure turbine and thence to the condenser. Auxiliary exhaust steam is admitted to the second stage of the low-pressure turbine.

TRIALS—CONTRACT REQUIREMENTS.

(*a.*) A progressive trial over a measured-mile course not less than 40 fathoms in depth for standardizing the screws, extending from maximum speed down to a speed of 8 knots.

(*b.*) A full-speed trial of four hours' duration in the open sea in deep water, at the highest speed attainable; the average for the four hours to be not less than 29 knots an hour, to be determined by the average revolutions of the main shafts, according to the official standardization curve.

TABLE-I STANDARDIZATION. U.S.S. "ERICSSON" MAY 18, 1915.

NO. OF RUN	TIME ON COURSE MIN	TIME ON COURSE SEC.	SPEED IN KNOTS	R. P. M. STAR'BD.	R. P. M. PORT	R. P. M. MEAN	S. H. P STAR'BD.	S. H. P PORT	S. H. P TOTAL	MEAN OF GROUP SPEED	MEAN OF GROUP R.P.M.	MEAN OF GROUP S.H.P.
1	8	18.8	7.22	126.65	124.87	125.76	86	91	177			
2	7	3.1	8.51	135.85	136.85	136.35	84	100	184	7.96	131.71	184
3	7	55.1	7.38	127.19	129.54	128.37	79	111	190			
4	5	2.8	11.89	196.03	191.64	193.84	291	289	580			
5	5	19.6	11.26	188.78	184.82	186.80	268	270	538	11.51	189.43	549
6	5	10.2	11.61	192.44	188.11	190.28	274	264	538			
7	3	44.1	16.06	262.97	267.47	265.22	780	813	1595			
8	3	50.5	15.62	263.05	269.74	266.39	699	887	1586	15.87	265.54	1561
9	3	42.7	16.17	261.11	267.19	264.15	694	781	1475			
10	3	00.3	19.97	343.87	343.83	344.85	1732	1802	3534			
11	2	56.3	20.42	343.09	342.07	342.58	1718	1709	3427	20.08	341 32	3400
12	3	4.5	19.51	338.38	332.13	335.26	1653	1538	3211			
13	2	26.0	24.66	437.24	436.37	436.18	3866	4068	7934			
14	2	31.0	23.84	436.27	437.16	436.72	3803	4049	7852	24.25	436.96	7860
15	2	26.1	24.64	438.12	437.06	437.59	3792	3968	7760			
16		NOT USED										
17												
18	2	16.5	26.37	503.60	512.54	508.07	*	*	*			
19	2	16.4	26.39	503.81	510.09	506.95	5825	6185	12010	26.45	508.50	12180
20	2	15.1	26.65	507.63	516.40	512.02	5863	6488	12350			
21	2	5.1	28.78	605.33	625.58	614.76	8703	9378	17479			
22	2	2.2	29.46	601.57	615.79	608.68	8257	9155	17412	29.06	610.75	17416
23	2	6.1	28.53	604.31	617.44	610.88	8220	9142	17362			
24	2	0.5	29.88	607.07	622.19	614.63	8332	9325	17657			
25	2	6.3	28.50	609.24	622.63	615.94	8513	9256	17769			
26	1	59.6	30.10	608.25	623.60	615.94	8349	9347	17696	29.33	616.98	17796
27	2	6.1	28.55	612.61	625.47	619.04	8598	8575	17973			
28	1	58.4	30.41	612.25	626.38	619.32	8555	9274	17829			

* NO S.H.P. OBTAINED ON THIS RUN.

(*c.*) A fuel-oil and water-consumption trial of four hours' duration in the open sea in deep water, at an average uniform speed of 24 knots, as nearly as possible. The trial to be conducted as nearly as possible to service-cruising conditions.

(*d.*) A fuel-oil and water-consumption trial of four hours' duration in open sea at an average uniform speed of 15½ knots, as nearly as possible under conditions similar to the preceding trial, but with the cruising engine *connected* and in use.

Additional two-hour trial at about 15½ knots with main turbines only, oil and water consumption to be carefully measured.

U.S. TONGSON
SPEED AND SLIP
SPEED AND SLIP
SPEED AND SLIP

TABLE II TRIAL DATA U.S.S. "ERICSSON."

	4 HOUR FULL POWER	4 HOUR 24 KNOT	4 HOUR 15½ KNOT	4 HOUR 12 KNOT	2 HOUR 15½ KNOT
DATE OF TRIAL	MAY 19,15.	MAY 20,15.	MAY 20,15.	MAY 18,15.	MAY 20,15.
DISPLACEMENT (corrected Pendings) TONS	1087.4	1097.8	1089.2	1096.3	1106.
DRAFT, MEAN, FEET AND INCHES	9-8⅛	9-10⅛	9-9⅛	9-9⅛	9-10⅛
SPEED, KNOTS	23.39	24.115	15.496	12.036	15.493
PROPELLERS, SLIP, PER CENT, STARBOARD	24.48	12.68	-6.16	1.04	3.25
PORT	27.23	13.79	16.75	3.35	3.30
MEAN	25.86	13.24	5.29	5.20	6.58
R.P.M., STARBOARD SHAFT	609.60	430.33	232.77	+189.92	249.65
PORT "	627.45	436.09	248.01	207.32	268.05
MEAN	618.02	433.32	240.39	198.62	258.85
ENGINES IN OPERATION	TURBINES		TURBINES & CRUISING ENG.		TURBINES
S.H.P. AVERAGE, STARBOARD	8267	3740	326	243	622
PORT	8884	3410	773	173	508
TOTAL	17151	7150	1099	420	1131
I.H.P. AVERAGE, CRUISING ENGINE			770	165	
NUMBER OF BOILERS IN USE	4	3	1	1	1
BURNERS USED (II PER BOILER)	10.31	7.42	6.5	4	8
HEATING SURFACE USED, SQUARE FEET TOTAL	23936	17952	5984	5984	11968
PERS.H.P.	1.347	—	—	—	—
PRESSURES, AVERAGE:					
MAIN STEAM, AT BOILERS GAGE	259.44	250	245.63	248.13	243.75
IN ENGINE ROOM "	248.25	241.5	241.5	239.88	238.68
CRUISING ENGINE, HIGH PRESS. CHEST "	—	—	208.75	91.25	—
L.P. RECEIVER "	—	—	31.	43.75	—
L.P. EXHAUST "	—	—	32.61	20.25	—
MAIN TURBINES, H.P. STEAM CHEST, ABS.	249.0	209.88	25.75	20.25	55.88
L.P. "	25.0	12.50	2.56	2.38	3.88
H.P. 1ST. STAGE "	246.69	106.63	21.50	18.50	26.88
L.P. 2ND. "	13.75	10.69	4.94	5.31	5.0
GLAND STEAM GAGE	3.98	40.0	4.63	3.9	4.0
AUXILIARY STEAM "	250.13	245.63	236.63	228.43	256.88
EXHAUST "	7.33	4.05	9.44	2.19	7.56
VACUUM, MAIN CONDENSER, INCHES MERCURY	28.18	29.20	27.94	28.88	29.21
BAROMETER " "	30.23	30.30	30.24	30.00	30.26
AIR IN FIRE ROOMS " WATER	6.38	4.52	3.69	2.43	1.83
FEED WATER AT HEATER OUTLET, GAGE	305.98	304.38	330.63	307.5	320.
IN FEED HEATER SHELL "	5.5	3.13	7.63	8.63	5.13
FORCED LUBRICATION SYSTEM "	10	10.03	9.75	10.11	10
FUEL OIL SERVICE PUMPS, DISCH. "	175.47	126.25	146.43	142.5	121.88
BOOSTER " "					
PRESSURE TO BURNERS "	169.38	122.5	143.13	125.75	123.75
LUBR. OIL PRESSURE TO CLUTCH "	—	—	70	70	—
TEMPERATURES, FAHRENHEIT:					
OUTSIDE AIR	59.88	61.88	59.63	60.5	60.5
ENGINE ROOM	82.69	88.25	89.88	91.38	89.5
AUXILIARY ROOM	90.13	91.88	91.38	94.75	93.43
FIRE ROOMS	86.25	87.32	86.25	98.25	97.25
MAIN INJECTION	55.44	54.38	57.00	58.13	57.13
OUTBOARD DELIVERY	71.13	64.50	58.25	59.13	58.88
MAIN AIR PUMP DISCHARGE	82.91	77.43	73.13	91.25	81.13
FEED TANK	83.38	79.63	77.38	83.38	87.38
FEED WATER (FROM HEATERS)	173.24	192.00	207.25	218.75	200.35
OIL TO COOLER	107.50	102.25	95.75	96.0	90.38
OIL FROM COOLER	93.88	90.75	86.75	84.0	82.38
WATER FROM COOLER	58.0	58.38	60.50	66.75	61.63
OIL DRAINS FROM BEARINGS, AVERAGE	108.0	101.95	94.55	92.67	90.73
FUEL OIL TO HEATERS	68.57	69.38	72.0	81.0	75.75
FROM HEATERS TO BURNERS	244.56	194.05	144.57	122.25	137.25
SMOKE PIPE GASES (PYROMETER)	616.36	511.88	481.88	415.13	390.0
R.P.M. FORCED DRAFT BLOWERS	1685.70	1297.29	1323.13	944.38	1078.13
MAIN CIRCULATING PUMP	717.81	573.75	442.5	596.25	586.25
DOUBLE STROKES PER MINUTE, OF PUMPS					
MAIN AIR	27.57	27.88	34.0	32.13	28.38
MAIN FEED	31.31	28.25	11.88	11.0	12.75
FIRE AND BILGE	32.36	32.38	44.0	42.5	38.5
LUBRICATING OIL	46.25	46.50	43.75	38.5	36.0
OIL COOLER CIRCULATING	73.88	68.0	46.5	43.75	48.0
FUEL OIL SERVICE	25.88	12.69	11.25	4.25	14.0
BOOSTER	42.19	37.25	23.25	—	24.5
WATER CONSUMPTION, ALL MACHINERY	28.6945	13.2933	4.0575	3.0662	5.4317
" " ALL MACHY. PER S.H.P. MAIN ENGS.	1.5.762	1.749	2.8.235	4.2.285	3.7.589
COOLING SURFACE, MAIN CONDENSER SQ. FT. PER S.H.P.	.603	1.496	7.526	17.008	7.474
FUEL OIL CONSUMPTION, POUNDS PER HOUR	2.18.756.4	93.85.39	2396.77	1494.47	2182.67
" PER KNOT PER HOUR	746.2	387.69	188.17	133.53	205.39
" " S.H.P. PER HR.	1.230	1.224	2.026	2.911	2.202
SPECIFIC GRAVITY	.8767	.8767	.8767	.8767	.8767
B.T.U. PER POUND	19474	19474	19474	19474	19474
POUNDS WATER EVAPORATED PER POUND OF OIL PER HOUR	12.818	14.211	13.349	14.588	12.070

(*e.*) An endurance trial of ten hours' duration in the open sea at an average uniform speed of 15½ knots, as nearly as possible, following as closely as possible trial (*d*), with cruising engine connected and in use. Fuel oil and water consumption will not be measured on this trial, the purpose of which is to determine the reliability and endurance of the cruising engine.

(*f.*) A fuel-oil and water-consumption trial of four hours'

duration in the open sea, with the cruising engine connected and in use, at an average speed of 12 knots, as nearly as possible.

Fuel-Oil Consumption Guarantees.—The contractors guaranteed that the fuel-oil consumption per knot run for all purposes, including that necessary for all auxiliaries in use on the trials, would not exceed 675 pounds at guaranteed maximum speed, 435 pounds at 24 knots, 200 pounds at 15½ knots, and 160 pounds at 12 knots, the consumption of fuel oil at these speeds to be determined by the Trial Board from a curve based on the rate of fuel oil consumed on trials (*b*), (*c*), (*d*) and (*f*), and corrected to a standard of 19,000 B.t.u. per pound of fuel oil.

INSPECTION NOTES.

By Captain F. W. Bartlett, U. S. Navy, Member.

FIBER.

There are two kinds of fiber, known to the trade as "hard" and "flexible."

Hard fiber is likewise known as "Vulcanized Fiber," "Hard Fiber," "Horn Fiber," etc., but the general name of "fiber" covers all of these and represents the material used so largely in the Naval service.

Soft fiber really means moist fiber. For this kind there is introduced in the bath liquids of various kinds to retain moisture in the product. Two of the common liquids are glycerine and solution of calcium chloride. Manufacturers have their secrets at this stage and claim better results than others in consequence. Beyond this the methods are alike, and the only other feature affecting the quality are selection of materials and care in manufacture.

Physical Qualities.—Fiber is unaffected by any of the ordinary solvents; it is not injured by immersion in alcohol, ether, ammonia, naphtha, turpentine or similar products; nor by any of the animal or other oils. It improves with age and is said to "season" as lumber does. It is believed that this improvement simply means lessened moisture. All fiber should season a month or more according to thickness.

It absorbs water very freely up to about 50 per cent. of its weight, and after being moist it warps and twists upon drying much the same as wood, although it will, after drying, resume its original thickness and qualities.

It is made only in sheets and tubes and cannot be molded.

Fiber will not melt under any circumstances and is not

readily burned, but at a very high temperature it chars and becomes brittle.

The tensile strength varies from ten thousand to twenty thousand pounds per square inch. Compression varies from forty thousand to sixty thousand pounds per square inch. Specific gravity is about 1.38.

Characteristics.—About the consistency of horn; good insulator; great mechanical strength; tough, tenacious, pliable, durable; capable of being sawed, turned, bent, embossed, drilled, threaded, cut, sheared, punched, etc., etc.

Sizes.—Sheets are approximately forty-five inches wide by seventy-two inches long and vary in thickness from five one-thousandths inch to two and one-half inches. Longer sheets may be furnished if desired.

Due to irregular shrinkage the sheets vary from forty-two inches to forty-eight inches wide and from sixty-six to seventy-two inches long. If needed of accurate dimensions they can be furnished to size at considerable greater expense. They should ordinarily be ordered about forty-five inches wide and about seventy inches long and the quantity in square feet paid for. Or payment could be made by weight, using twenty cubic inches to the pound.

Tubes are usually made with an inside diameter of ⅛ inch to 3 inches with any desired thickness of wall up to one-half inch and from two to three feet long.

Rods are furnished in random lengths up to 66 inches and in diameter from 3/32 inch to 2 inches.

Colors.—The color of the fiber depends upon the color of the paper of which it is made and there is no difference in quality due to the color. The common colors are red and black and a natural color approaching white. Manufacturers claim that uncolored fiber is best, as the coloring material used has solid particles, and prevents the perfect homogeneity necessary for best results. Many people are surprised that fiber is of any color but red. Uncolored fiber should always be ordered, except when colors are needed for ornaments.

Uses.—Fiber is an excellent insulator for electricity when dried and may be used for electrical purposes in all places that are always dry.

It is very useful also for condenser-tube packing, rollers, journals for light shaft gears of small sizes; likewise washers, brake bands, etc. It is particularly valuable in places where it is desired to deaden noises.

Method of Manufacture.—The best fiber is made from paper made from pure and specially selected cotton rags, and sometimes of cotton leavings, like waste. Cheaper fibers are made of cheaper material. This purity is necessary because this type of paper contains the greatest amount of cellulose that paper made by present methods contains. The need of the cellulose is so that it may be turned into a gelatine-like substance which acts as a glue and binder to the various thicknesses of paper. The paper is said in the trade, to be parchmentized. The process is usually carried out by the use of sulphuric acid. However, for fiber, zinc chloride is used instead of sulphuric acid and the paper is said to be "gelatinized," and fiber may be called a dried gelatinized cellulose.

The paper is made or bought in rolls of the trade width, and on its way to a pair of horizontal rolls is led through a solution of zinc chloride. This bath is only about six feet long and the paper dips into it and in that way becomes gelatinized. The paper is then led to the lower roll and is wound up on this roll, one thickness above another; the upper roll is comparatively light and merely rests on the top. Pressure is not particularly required as the fiber is made by the gelatinized surfaces of the paper sticking together and making practically a solid substance. If it were ideal it would be a concrete mass of gelatinized cellulose, but the paper carries this material and assists in making it stronger.

The rolls are hollow and heated by steam through the trunnions so that they are kept merely warm, not hot.

The rolling is continued until the required thickness is obtained. As it is found that this moist paper loses about one-

half of its thickness when dried, the material is rolled to about double the final thickness ordered. This shrinkage in thickness accounts for the great density and strength of the fiber. It is also found that this material becomes shorter than when rolled, so that it is always rolled about 20 per cent. wider than the final product is to be.

Finally, there is an annular roll of paper on the lower one of the rollers. When thick enough a horizontal cut is made of the paper on the lower roll and it is peeled off and flattened out.

The next operation is to clear the fiber of the zinc chloride, for two reasons. Zinc chloride will prevent using this material as an insulator. Also, zinc chloride is abstracted and used over and over as a question of economy.

There are many vats where this material is made; probably as many as one hundred, each one containing about the same quantity of water. The fiber is taken from the rolls and put in one vat after another to allow the zinc chloride to be entirely dissolved by the water, so that there may be none remaining in the final product. The length of time the fiber remains in each tank is a matter of experience. The water for these tanks travels in the opposite direction from the fiber. In other words, the purest water finally operates on the purest fiber. It is then pumped to the next tank and the water continues on, tank by tank, until the final tank, which is the one first receiving the fiber, becomes strongly saturated with zinc chloride. This is then pumped out and the water evaporated and the zinc chloride obtained for further use. The periods for changing the water depends on the results of experience.

This washing operation takes a long time. The operations of washing, drying, pressing and rolling for the varying thicknesses of the material take approximately the following lengths of time: ½ inch, 3 months; 1 inch, 6 months; 2 inches, 10 months.

This is the difficult feature of the business of making fiber, as once rolled to a definite thickness, this thickness cannot be changed, and if material in stock is of a certain thickness and

that thickness is never called for, there is an absolute loss of the entire process. In other words, it is necessary for a firm making fiber to make the different thicknesses on judgment of the market requirements. It is an absolute gamble as to whether they will ever sell different thicknesses or not, and a large sum of money must be kept idle to be ready for orders that may arrive, as it would be impossible to make the material of the thicker grades and fill any orders in reasonable time. With one firm, it is estimated that there was $1,000,000 worth of finished goods on hand.

After washing, the sheets are placed in dry houses. The idea in these dry houses is to imitate a warm summer day as nearly as possible, keeping them at a temperature of 90 degrees and have blowers arranged to change the air every forty-five seconds. When the fiber dries it curls up, shrinks and is very irregular in its shape.

After washing, the next operation is to press it flat by hydraulic pressure with steam-heated plates above and below. Those plates are of a temperature of 300 degrees, and the pressure on sheets 6 feet by 4 feet is 200 tons. Steam heat is used because fiber softens somewhat under heating, and the thicker the plate the longer the time required to be thus heated and flattened. When the operation is completed the fiber will remain flat. This heat and high pressure adds nothing to the density nor does it make the fiber thinner. The pressure put upon this material could not affect its density. This is simply a flattening operation after the drying.

The last operation is rolling or, as it is called in the trade, "calendering." The double horizontal rolls used weigh 5,000 pounds each and are held firmly with heavy screws at the ends. This is primarily done to make a better surface and is always part of the process. The thickness may be reduced somewhat by this rolling. As the material can flow a little, no harm is done to its qualities.

If close limits of thickness are required, sheets are picked

out slightly thicker than required and the calendering thins them to the proper amount.

Defects.—Much material is defective and its value and the labor expended is lost, as no use has been found for the waste due to faulty work, cuttings, drillings, etc., in spite of efforts made for years. Some defects are as follows and can be detected by observation:

(*a*) Iron in the paper that has escaped the close inspection of the rags and also the electric separator. This shows as a red coloration or rust spot. The iron, of course, ruins the fiber for electric work, and as this is the main use for fiber, the iron is closely watched.

(*b*) Blisters. These appear like blisters on wrought iron. The cause seems to be too uncertain for manufacturers to define accurately. It means that the layers of cloth are not glued together properly in places.

(*c*) Laminations at edges of plates are easily detected.

Stowage.—Fiber is stowed away in dry storehouses. The storehouses are not heated to any extent, although heat softens the fiber somewhat; but if heat is continued until all the water is gone from the fiber, it becomes entirely too brittle. Intense cold also produces brittleness. The stored material may be sold from storehouse or may be taken to the shops to be worked into shapes desired.

Manufacture of Tubes.—Tubes are made in the same manner, except that the paper is rolled on steel mandrels of proper inside diameter. As the paper is rolled on the mandrels it is carefully calipered, and when the desired thicknesses are obtained the paper is cut and the loose end rolled tight. The roll and mandrel combined are soaked in the same manner as mentioned before, and at the end of the soaking the mandrels are removed and new ones inserted. These new mandrels are the ones that positively settle the inside diameter of the tube, as the fiber dries closely to the mandrel, and as this fiber dries it shrinks to one-half the thickness as put on, making a very hard substance with a clear and accurately dimensioned hole

in it. Later on, after calipering to size, these mandrels are forced out. By driving square mandrels into the wet tubes, approximately square tubes are made.

Rods.—Rods used of this material are made from flat sheets. Sheets are sawed to size and turned round just as wood would be treated.

Manufacture of Various Articles.—Except for certain articles with holes lengthwise which are made from tubes, articles manufactured from fiber are made from sheet material; the nearest thickness is taken, and then it is a question of working this material, just as wood would be worked. It is astonishing to note the multitude of articles made from fiber and how its use is extending in all directions for purposes never thought of before. It is particularly advantageous where lack of noise is to be considered and where it is necessary to work in various acids and alkalies.

Threads.—It is difficult to secure good threads on fiber in many cases, and this is the principal fault that has been found with this material, as manufacturers expect more of material in this line than can be easily accomplished. It will be remembered that the paper is put on the roller in layers, so that when flattened out it leaves a definite lengthwise fiber of paper, like the grain in wood. When the thread is cut, therefore, on a round rod, on two sides diametrically opposite, there will be found the extension of these paper layers, and in threaded work, it is often possible to discover by close inspection just which way the grain runs. It is these paper edges, or where the percentage of the paper is greatest, that cause the difficulty in cutting the threads, and special care should be taken in this kind of work. Excellent threads are made repeatedly by manufacturers, but the details of care required are not generally known, so that trouble may be experienced at navy yards and aboard ship from endeavoring to thread this material. Manufacturers claim that if poor threading follows, it is due to poor material to a large extent. Always order "uncolored horn" fiber when difficult threading is to be done.

Care in Working Material.—It is important that this material should be worked dry, as it is very sensitive to moisture. It must not be too dry or it will be too brittle. However, if kept in a very dry storeroom and found brittle, the material may be placed out of doors under cover and in a few days the proper amount of moisture will be absorbed. Separate the sheets to let the air get at them. The exact amount of dryness would have to come by experience. It should be kept as dry as it can be worked properly, if extreme accuracy is required. Fiber is like wood. It will shrink sideways of the grain and not endways. For instance, if a ring of this material is cut when it is wet, the next day it will be found out of round, and holes drilled accurately one day will be considerably out of place the next. Articles have been sent to users of this material and returned with the complaint that they were too large and would not fit. This is due to their becoming moist, as it is known that this material will swell, as it absorbs about 50 per cent. of its weight and swells about 30 per cent. if thoroughly wet. If a small article is found to be too large to go into place, it should be dried for a few days and it will be satisfactory.

Condenser Ferrules.—In the Navy, fiber has been extensively used for condenser ferrules and with varying reports of success. Some claim the very best of results and some claim almost disastrous results. It is believed that this is largely due to the fact that the ferrules were not of the right size to begin with. It has been found from experience that the annular spaces around the condenser tubes vary considerably, depending on where the condensers were made. It is also found that in an old condenser where the threads have been retapped there is a great irregularity, and difficulty has been experienced in putting in corset lacing with tools that worked well with the ordinary annular space. If the fiber is ordered to a size to just fill this annular space, it will then swell after being set up and wet to about 30 per cent., if free, so that it would entirely fill

diametrically, the space, and will make a tight joint, when the gland simply makes a tight joint at the end.

If the ferrule is quite small so that it cannot soak up enough moisture to swell diametrically and entirely fill the space, the end pressure of the gland cannot accomplish the desired result and make it swell throughout its length diametrically. The gland may make a tight fit in its proximity, but the whole length cannot ever be forced by the gland to the proper fit. Therefore, it is advisable for those using these ferrules to see that they are a fairly tight fit when dry. Any size may be ordered and made with extreme accuracy, but the ordinary stock ferrule may not fit all spaces.

ELECTRIC HIGH-PRESSURE FIBER OR BAKELITE-DILECTO.

This material is coming into extensive use in the Navy for wireless work. It is capable of extreme resistance to electricity.

Method of Manufacture.—This is along the same general lines as with fiber, but the quality of the paper is not so important, as the paper in this case mechanically picks up in the bath bakelite, which acts as a glue, whereas in the other case the paper had to be capable of gelatination and of itself glue the layers together. In this case the bakelite is the important thing and is used as a thick liquid in the bath. The paper simply makes the product less brittle than it would otherwise be and adds to its strength. Sometimes canvas is used instead of paper where great mechanical strength is required.

In making this material the object is to retain the chemical, so that no washing follows. The material is rolled to the required thickness, layer upon layer, and dried, and is subjected to heat and pressure for flattening. The same press flattens this material that flattens the fiber. After this flattening process the material is calendered. It is then ready for use.

The manufacture of this material is rapid, and orders may be taken for prompt delivery. There is no question involved of a large idle capital, as that in fiber, nor of prospective cus-

tomers. The reason this material is so expensive, is on account of the cost of the expensive material used. The main cost is for bakelite.

Bakelite.—Bakelite is a secret material, and different companies have been subsidized to use it in the manufacture of insulations. It may be used alone and cast or pressed to the desired shape, but in this form it is very brittle and it is difficult to do anything with it, so that strength and durability can only be obtained by using paper or canvas as carriers of bakelite.

MAGNESIA PIPE AND BOILER COVERING.

Source.—Magnesia for pipe and boiler covering is made from limestone or dolomite containing as much magnesium carbonate as can be found. One firm has rock of this kind containing about 40 per cent. of magnesia. The works are generally at the deposit, to save freight, and a cheap method of quarrying and conveying the rock is devised.

Calcining and Slacking.—The rock is a mixture of calcium carbonate and magnesium carbonate, from which the calcium must be removed. The rock is first calcined, using charcoal as the fuel. This is done in the usual way for making limestone. The resulting rock is the combined oxides of calcium and magnesium. In other words, the carbonate has been changed to the oxide for both elements. The carbonic acid gas thus produced is used later. The calcined rock is next mixed with water in special rotating vessels where the lime is slaked. All impurities remain in the vessel and all the lime is carried away by the overflowing water during the operation. The oxides are now in a state of suspension in the water, the percentage of solid material being very small. The later processes consist in a juggling of "states of suspension" and "of solution" to separate the calcium and the magnesia.

Carbonating.—The liquid is pumped into vertical metal cylinders of proper size (in one case noted, about five feet in diameter and about fifteen feet high), which have, leading from the top head to near the bottom, pipes for the entrance

of CO_2 derived, as noted above, from the calcining. This gas is pumped from the calcining kilns and returned to these cylinders under a pressure of about 70 pounds. It rises through the liquid, being absorbed by the oxides in suspension in the water, and reconverts them into carbonates. But this operation produces an important difference in the condition of the two carbonates; after the operation the calcium carbonate is in suspension and the magnesium carbonate is in solution.

Elimination of Calcium Carbonate.—The next step is the separation of the materials. The separation is achieved by a system of filtration. A series of cells of wood, perforated by small holes and lined with cotton canvas or cloth, act as filters. The liquid enters the interiors of these cells. The water passes out, carrying with it the material in solution (magnesium carbonate) and the material in suspension (calcium carbonate) is caught in the meshes of the cloth as a paste. Frequently the cells have to be opened up and the cloths stripped from the frames for the removal of the calcium carbonate. The cloths, after cleaning, are used again for filtering. This is the end of the calcium carbonate as far as this process is concerned.

Final Process.—The water containing the weak solution of magnesium carbonate is next put into other vertical cylinders of about the same size as above and is there heated by steam to about 190 degrees F. At this temperature the magnesium carbonate becomes again in suspension instead of in solution. The liquid is then pumped to open vats lined with thin cloth and most of the water is drained off, just enough remaining to allow the mixture to be pumped to the molds.

Molding, etc.—The molds are made on the same principle as the cells described above, with the same size of holes and the same kind of cloth. Many cells are placed beside each other and pressed together firmly and the liquid is allowed to enter them all at once. When all are filled so that no more liquid flows from the openings, the cells are opened. The material

that was in suspension has been retained by the filtering process and the mold is filled with this magnesium carbonate.

This substance is used for the drug trade, and is later cut up into ounce weights by a band saw.

The magnesium carbonate used for pipe or boiler covering has to be mixed with some other substance so that the resulting mixture may not be so brittle. Asbestos fiber is used for this purpose. The mixing occurs in special vats by special apparatus.

The molds for pipe covering and for valves, etc., are made in the same general manner except that cores are made as in foundry work and the outside of the cells correspond to the shape desired. This work is generally done in individual presses.

After the molds are made they are dried. This takes about six days in special extensive ovens. Later the molds are treated as if they were made of wood in as far as the methods of completion of shape are concerned. Planers doing exactly the kind of work done by wood planers shape the outsides and insides. The material is cut to exact length by saws. Later thin canvas is pasted on the pipe and valve coverings and the completed product is shipped.

SMALL SHAFTS.

A certain firm makes a specialty of small shafting, particularly small crank shafts. Inasmuch as it does not make the material, the firm's financial success must depend entirely upon its special methods in shaping the material, which the consumer might purchase from the firm's competitor who makes the material and likewise makes small crank shafts.

Certain special appliances used by this firm are noted here.

Pressing Shafts.—This firm's output of very small shafts competes with drop-forged shafts, but a press is used in manufacture in place of the drop forging. The usual method of drop forging is cheaper, but it is contended that the pressed

material is in better and more uniform condition than that made by the drop-forging method; the suddenness of the blow in drop forging failing to allow the metal time to be thoroughly worked and to shape itself without leaving portions in a constricted condition.

Metal Saws.—A special type of circular saw seems to do unusual execution and to cost less for replacement of blades than other saws. The circular disc has on its outer circumference, staggered enlargements on either side to receive short cutting tools. The grooves for receiving these tools are made with extreme accuracy and measured to about one-half thousandth of an inch. The tools themselves are of bar steel ground accurately to fit the grooves. The grooves are made long enough for a tool 4 inches long, and when the tool is first put in place it is driven into position with considerable force from a hammer. There is no wedge of any kind to hold the cutting tool in the disc, the friction due to the close fit being sufficient to hold it securely. It would seem at first that this is impossible, but it must be remembered that pressure against the cutting tool is practically all tangential. The small amount of force tending to drive it radially is successfully resisted by the tightness of the driven fit. These cutting tools, when dull, can be resharpened; and it is found that they can be utilized in this way until the original 4 inches is reduced to about 1½ inches, so that only about ¾ inch is left for the fit in the wedge. It is found that even this short distance is ample, and is sufficient to keep the tool from moving radially. The groove for the tool is out of the middle radial plane of the disc a slight distance, so that the outside cutting edge on either side of the disc is slightly beyond the disc, giving clearance so that the disc will never rub against the work. The cutting tool is also sloped back a little for clearance.

These saws have been supplied to the trade for many years, and it is seldom that a new disc is required, but new cutting tools are constantly furnished. It is found that the fit is so accurate and the wear in the groove is so imperceptible that

for nine years not a complaint has been received of the fit of these cutting tools when supplied.

This is a remarkably clean-cutting saw, and the cutting tools produce a cut about ¾ inch wide for the smaller sizes and wider cuts for larger sizes. The saw is used for sawing off lengths of shafting and for any other sawing. In some cases, where short lengths are required, two or more saws are placed on the same mandrel with distance pieces between them, and all cut at once. These saws are particularly valuable for working on the crank shafts. The webs are forged solid and a portion from the web has to be removed. No method better than drilling has yet been discovered for the line nearest the pin. In some cases a single large hole is drilled, then two saws are arranged to cut in to the edge of this central hole, leaving only slight fins on either side which are easily broken off. This method of removing material from between the webs is a steady operation and is much better than the method of having the webs swing around in the lathe to receive a sudden jolt as the shaft strikes the fixed tool.

Also, the double saw cleans up the outside of the webs in one operation. Sometimes one cut is sufficient to take off the extra material, but when more are necessary a special saw is used. This saw is designed on the same general principle as the one mentioned above. The cutting tools are arranged in sets of three, staggered longitudinally across the rim of the disc. Thus during all parts of the cutting one cutting tool takes off its width, and the next one is just outside of it and takes off another width, and a third one takes still another width. In this way the sets of three cutting tools combined will take off a width of an inch or more on each side of the web. This saw produces most remarkable results in the saving of labor and cost.

When the saws are dulled, they are sharpened by revolving them against revolving cutting wheels of emery or other abrading material.

Lathes.—Another special feature is a type of lathe used.

This lathe has a face plate at either end, both ends being driven by power which is carried along a square shaft from one end of the lathe to the other. The driving is done by pinions on this shaft through gear wheels on the head and tail face plates. These two face plates have holders on them for gripping the shafts, and no centers are used. The shaft is gripped by the holders in a central position. There are circumferential and radial adjustments for the holders, and accurately marked scales. After the shafting is gripped it is centered by the scale marks, so that the main bearings may be turned. To turn the crank pins the holders at each end are shifted a distance equal to the throw of the crank, as measured on the scales. This produces a remarkably quick shaft centering, and is absolutely accurate as long as the lathes are in good condition. As certain shafts made by this firm have as many as five or six cranks, the rapidity of this operation is extremely valuable. In addition to the radial adjustment the circumferential adjustment allows the shifting of the shaft the required angular distance between the axes of the several pins, by using the circumferential scales. This also is rapid and accurate.

There is a third support for the shaft near its middle length. This support has the appearance of a steady rest and does execute that function. But there is an annular wheel within the outer casting which circumscribes and grips the shaft, and this annular wheel is driven through gearing by the square shaft above referred to. The square shaft allows this central support to be moved as needed. With this additional driving support there is little danger of sagging of the work. Also, besides the cutting tools at either end and near the face plates, a third cutting tool is used for any "middle length" pin or journal on the same axis that may require turning.

A support near the tool along the middle of the shaft is very important for accurate work.

Grinding Pins.—After the journals and pins are turned they

are ground on a lathe in which a similar system of two face plates is used, which again allows for quick adjustments for the various positions of the journals and pins. The grinding wheel has the usual movement towards and away from the shaft and also a lengthwise movement, so that the grinding is a very rapid operation.

The fillets also are ground in the same lathe using a different grinding wheel.

During the grinding the sides of the webs are slightly touched in places by the abrading wheel, but no attempt is made to grind them smooth.

Time and Labor Saved.—These two operations of sawing and turning with special apparatus are so effective that for years this firm has been able to compete successfully with firms that manufacture their own material and likewise make the finished product.

SCALPING METAL.

In an establishment for making phosphor-bronze and other special material of like nature, after the slabs are cast and rolled once the entire surface of the slab is "scalped." This is done to remove the skin with its uncertain composition, rendering the slab unsuitable for use where most pure material must be employed. The operation also allows of an accurate inspection of the surface for possible defects or segregation and the digging out of deep impurities.

The machine is of the shaper order, with the cutting operation done during the pull towards the machine instead of, as usual, during the push from the machine. From the head of the shaper there extends an arm working on a hinge, and on the end of this arm is the holder for the cutting tool. This allows of a vertical motion of the holder and tool. In addition the bed holding the slab being scalped is easily pushed sideways by a quick-action wheel and gear, and raised or lowered as desired by a lever pressed by the foot of the workman.

The cutting tool is of steel of about 5/8 inch by 1¼ inches, and the cutting edge is on the bottom and of the wider dimension. This edge is shaped so that it tends to dig into the metal and scrape or scalp it off. It is like the finger nails scraping the top of a cake of wax. The tool is inclined about 15 degrees from the vertical, the top farthest out from the head of the shaper. This angle assists in giving the proper grip to the cutting edge. A cam lifts the cutting tool on the return stroke and a heavy spring pushes it down when cutting.

The action is rapid. Each completed stroke takes less than half a second and each stroke gouges off a bit of the surface, the cut-off pieces of the metal looking like shavings as they fall. The operator rapidly shifts the position of the bed and pays no particular attention to having one cut follow accurately next to the preceding one. He guides the tool across once and then back and again along, as seems necessary to him, occasionally digging out a deep groove where a deep pit shows. The resulting appearance of the surface is of a lot of irregular gouges on the bright metal. The material is clamped very simply in place and three operations are required, as the stroke of the shaper is only about a foot. Little time is lost on the shifting endwise to complete the three sets of scalps or in doing the same to the other side. The ends and sides are not scalped, but are sheared off.

MACHINE FOR WIRE DRAWING PHOSPHOR-BRONZE.

A machine was noted where there were on each side of it six drawings of wire at the same operation without annealing the wire between the drawings. The wire was on a roll at one end and passed at once through the first die, the power for the drawing being supplied by a disc beyond the die. The disc was power driven, and two turns of the wire allowed enough grip to pull the larger portion through the die, the last three discs having three turns of the wire. From the first disc the wire led to the second die, the power supplied by a disc beyond in the same manner. Thus two sets of six operations

went on within a length of twelve feet and the wire was finally wound automatically on spools. Nobody was near the machine, which was automatic, and required occasionally a new bundle of wire.

Of course each disc had to revolve faster than the preceding one, to allow for the increased length of the wire, the ratio from slowest to fastest being about twenty-four to sixty-four revolutions per minute. The wire was reduced in diameter from .220 to .091 inch and the power required was 100 I.H.P.

METHOD OF TESTING SAFETY VALVES AT THE U. S. NAVAL EXPERIMENT STATION.

By ENSIGN L. R. FORD, U. S. NAVY, MEMBER.

OBJECT OF TESTS.

1. The object of most of the safety-valve tests made at the U. S. Naval Experiment Station is to determine whether the valves purchased for installation on naval vessels fulfill the requirements of the specifications prepared by the Bureau of Steam Engineering. Occasionally special tests are made to try out new types of valves, or in compliance with the request of other Departments of the Government, but the tests of naval valves are characteristic of the test methods at the Station.

2. The requirements for the safety valves of the U. S. S. *Nevada* are characteristic of the requirements for most valves contracted for at the present time for use in the service. They are covered by the following extracts from the machinery specifications:

(*a.*) "The valve, while discharging, must be quiet and free from chattering. Simmering will be allowed at 2 pounds before popping, but the valve closure must be sharp."

(*b.*) "The valve must be adjustable from a 5-pound to a 12-pound blowdown, without disassembling the valve, and without causing chattering."

(*c.*) "The spring will be of material round or square in cross-section and of such length and diameter that the fiber stress will not exceed 48,000 pounds per square inch when the spring is compressed to the position it would assume were the valve lifted so as to give its rated discharge."

(*d.*) "Two boiler safety valves, and such other safety valves as the Bureau of Steam Engineering may direct, shall be

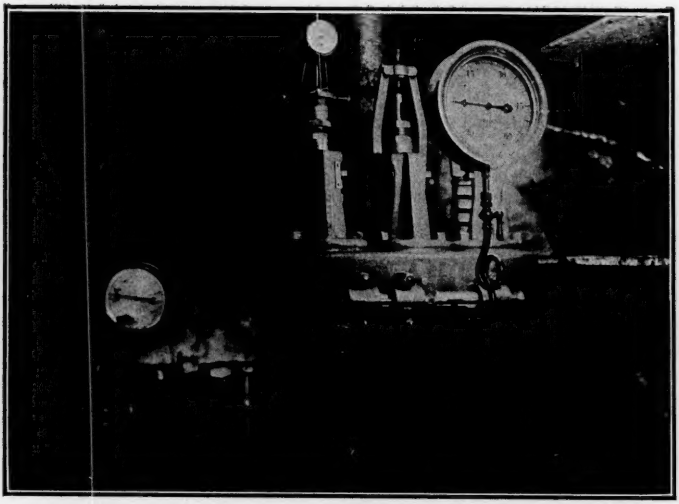
selected at random by the Inspector of Machinery and forwarded to the Engineering Experiment Station, Annapolis, Md., for test. The valves when lifted by steam must lift one-tenth of an inch to fulfill the requirements of the specifications."

3. During the progress of these tests data are obtained that are often of value in preparing new specifications and improving existing designs.

GENERAL ARRANGEMENTS FOR TESTS.

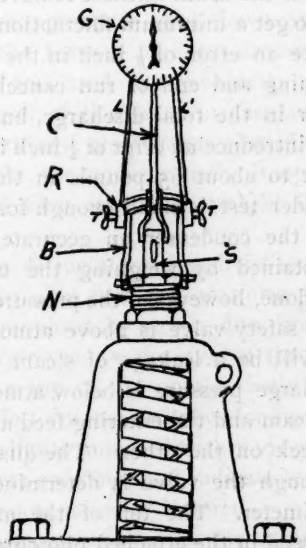
4. For all safety-valve tests the valves are mounted on a Mosher, marine-type, oil-burning boiler containing 4,537 square feet of heating surface. The steam drum is 48 inches in diameter and 14 feet long. A 6-inch gate valve is bolted to the drum nozzle, and the inlet flange of the valve to be tested is usually clamped to this valve. Quick regulation and sure control of the steam pressure is afforded by the oil burners. If increased pressure is desired more burners can be quickly lighted, and if complete cessation of evaporation is desired it is the work of but a few seconds to cut out all the burners. This close control of pressure expedites the work and saves fresh water. The exhaust steam is discharged through a sheet-iron pipe into the atmosphere outside of the boiler compartment. In the case of a small valve this discharge is led to a condenser, but if a large valve is being tested the quantity of steam discharged is too great to be handled by the small condensers at the station.

5. The lift of the valve is measured by a micrometer lift gage, which may be seen mounted on one of the valves in the photograph. The details of this gage and the manner of connecting it are shown in the sketch. A base B is shaped at its lower end to fit over the spring-adjusting nut N, and is secured to this nut by small set screws. The gage G is supported by the standards L and L′, on a bottom ring R. This ring is secured to the base by means of the thumbscrews TT. Thus all parts of the gage except the connect-



ARRANGEMENT OF SAFETY VALVES AND FITTINGS FOR TEST.

ing rod C are connected rigidly to the body of the safety valve. This connecting rod is secured to the moving stem of the valve. Any lift of the valve is, by means of the connecting rod, communicated to the rack and pinion inside of the gage, and this rack and pinion moves the pointer. The face of the dial is graduated to read to thousandths of an inch.



The steam pressure is indicated by two pressure gages, one mounted directly on the boiler drum, the other connected to the gate valve above its seat. The latter valve can be seen at the left of the photograph. The large gage shown at the right of the photograph is mounted on the safety-valve casing to indicate the pressure in the discharge chamber of the valve.

6. After the tests for lift, simmering, blowdown, chattering and closure are completed the capacity tests are made. The valve is allowed to blow continuously for one, or sometimes two hours. A measure of the weight of steam discharged by the valve is obtained by measuring the water fed to the boiler, since there are no outlets for steam from the boiler, other

than through the valve, the feed pump being operated by steam from another boiler. The water is measured by the drop of water level in a calibrated feed tank. The water level in the boiler is noted at the same instant as in the feed tank. In this reading of the water level in the boiler lies the greatest source of error in the test. The level is read from a gage glass at the end of the drum farthest removed from the steam nozzle in order to get a minimum fluctuation of level, but it is possible to make an error of $\frac{1}{8}$ inch in the readings. If the errors at beginning and end of run cancel each other there will be no error in the total discharge, but if the errors are additive, it will introduce an error of $\frac{1}{4}$ inch in the drum water level, equivalent to about 65 pounds in the total discharge. If the valve under test is small enough for the discharge to be handled by the condenser an accurate measure of the discharge is obtained by weighing the condensed steam. This cannot be done, however, if the pressure in the discharge chamber of the safety valve is above atmospheric pressure, because there will be a leakage of steam from the casing. When the discharge pressure is below atmospheric pressure the condensed steam and the entering feed are both weighed, one being a check on the other. The quality of the steam discharging through the valve is determined by means of a throttling calorimeter. The top of the attached mercury column can be seen in the attached photograph. The sampling pipe of the calorimeter projects about one-half inch into the steam current. The discharge pipe is run to the bottom of a tank of cold water, mounted on platform scales, so that the amount of water discharged by the calorimeter can be measured. To make the capacity run the number of burners in operation is increased until the valve remains open at the desired lift. This lift is maintained very close to the desired value by regulating one burner under the boiler, by signals to the fireman. When the conditions become constant the run is started, the steam pressure and valve lift being read at one minute intervals, while the feed-tank level, boiler-drum water level, calorimeter pressure and temperature and safety-valve casing

pressure are noted, at five-minute intervals. Popping pressure and blowdown observations are made just before and just after each run.

7. To provide against the introduction into the weight of steam discharged of an error due to leaks around the boiler and its fittings, a leakage test, of the same duration as the capacity test, is made, after the capacity test has been completed. The feed pump is shut down and enough fire is maintained in the furnace to keep the same steam pressure in the boiler as was used in the capacity test. At frequent intervals the level of the water in the boiler is read and at the end of the test these readings are plotted. Since the boiler used is very tight, the curve usually droops off very slightly at the start and then remains a straight line for the rest of the test.

8. A platform of metal grating, built level with the top of the drum, serves as a working platform for the observers. Ventilation is provided by an air duct from the forced-draft blowers, discharging above the level of the working platform. Mounted on the top of the uptake, within easy reach from the operating platform, are switches for signaling to the fireman. Electric lights mounted within view of the fireman are operated by these switches, and indicate to the fireman when the pressure is to be raised or lowered.

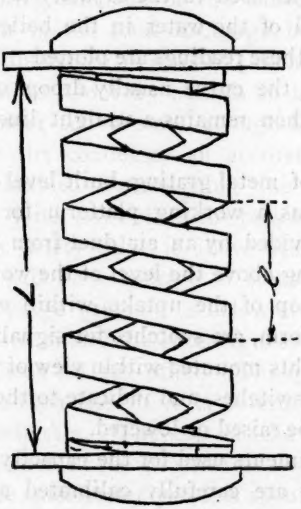
9. All the instruments used for the capacity, lift and blowdown observations are carefully calibrated and calibration sheets made out, to be used in the final calculations.

TEST OF SPRINGS.

10. After the tests for lift and blowdown are made, and before the capacity runs are started, the valve is dismantled for examination and test of the springs.

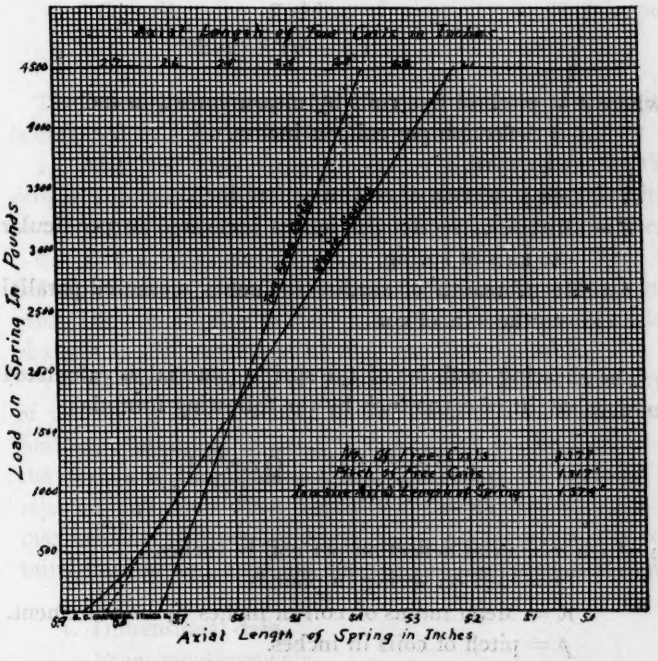
11. The springs are compressed in a testing machine, between two cast-iron discs with spherically-shaped ends, as shown in the sketch. A lug on the face of each disc fits into the spring and serves to hold it into position. The length L is measured by micrometers for various loads, from zero to the

maximum, then to zero again. Due to the formation of the ends of the spring to form a solid bearing, the number of coils available for actively resisting the deflection of the spring is less than the total number of coils. At loads near zero all the coils act, but as soon as the load increases, the tapered coils at the ends press against the next coils and become inactive. This is shown on the attached curve, where the line of deflection curves to the left when the end coils are active. To obtain the number of free coils and the inactive length of



the spring a curve of deflection is plotted, using the length L in the sketch. A curve of deflection for two free coils for the same loads is also plotted, using the length *l*. In the attached curve the deflection of the whole spring, for a load of 4,500 pounds is 5.824 — 5.216 = —0.608 inch, while the deflection of the two free coils is 2.633 — 2.273 = 0.360 inch, or the deflection of one free coil is 0.360 ÷ 2 = —0.180 inch. Then the number of free coils in the spring is 0.608 ÷ 0.180 = 3.378. At loads near zero all the coils become active, as shown by the curvature of the line of deflection. The length

5.824 is obtained by prolonging the straight part of the line. Take any load, say 2,500 pounds, then if the length of two active coils is 2.434 inches the active length of the spring at a load of 2,500 pounds is $3.378 \times 2.434 \div 2 = 4.111$ inches. Since the total length of the spring at this load is 5.484 inches, the inactive length is $5.484 - 4.111 = 1.373$ inches.



12. The maximum fiber stress in the spring occurs at the middle of the inside edge of the section of the spring coil and is made up of the four component stresses due to torsion, direct shear, bending and direct compression. The effect of the last two is slight enough to be neglected. The first two produce a maximum shearing fiber stress, which is calculated for a valve lift of 0.100 of an inch by the following formula:

$$S = \frac{9\,Q \cos\theta\, R}{2bh^2} + \frac{Q \cos\theta}{A}$$

in which Q = load on spring in pounds.
R = mean radius of coil measured from the axis of spring to center of gravity of section in inches.
θ = angle of inclination of coil to plane perpendicular to axis of coil.

$$\cos\theta = \frac{2\pi R}{\sqrt{(p-d)^2+(2\pi R)^2}}$$

where p = pitch of free coils by measurement, in inches.
d = deflection per coil, in inches.
π = 3.1416.
A = area of section of coil in square inch.
h = altitude of section in inches measured perpendicular to axis of spring.
b = Mean breadth of section in inches measured parallel to the axis of coil.

The shearing modulus of the spring material is calculated for a valve lift of 0.100 inch by the following formula:

$$d = \frac{Q\cos^2\theta\, R^2 L}{C J G} + \frac{Q\cos^2\theta\, L}{A G},$$

in which d = axial deflection per coil in inches.
Q = load on spring in pounds.
R = Mean radius of coil in inches by measurement.
p = pitch of coils in inches.
$L = \sqrt{(p-d)^2+(2\pi R)^2}$ = length of one free coil in inches actively opposing the compression of the spring.

$$\cos\theta = \frac{2\pi R}{L}.$$

C = St. Venants constant for the resistance to torsion of bars of nearly square section.

$A = h \times \frac{B+b}{2}$ area of section in square inches.

h = altitude of trapezoidal section in inches.
B = larger base in inches.
b = smaller base in inches.

$$J = \frac{h}{48}\left[B^3 + B^2b + Bb^2 + b^3\right] + \frac{h^3}{36}\left[\frac{B^2+4Bb+b^2}{B+b}\right]$$

= polar moment of inertia of trapezoidal section in inches.

G = Shearing modulus of elasticity in pounds per square inch.

The numerical value of the shearing modulus of elasticity is obtained by substitution in this formnla.

13. After the tests are completed the valve is set for the proper popping pressure on the boiler and is shipped either to the manufacturer or to the ship on which it is to be used.

14. If the valve develops any defect during the tests, or fails to function properly, the manufacturers are notified and given the opportunity to send a representative to make such changes or adjustments as he may consider desirable.

15. At the conclusion of the tests the engineer in charge of the test makes a report to the Head of the Experiment Station, containing in detail a description of the conduct of the test, a recommendation that the valve be accepted or rejected, and such other remarks or recommendations as he may consider pertinent or desirable. This report usually contains information and data derived and tabulated as follows:

1. Dimensional data.
   From measurements.
2. Popping pressure under valve, pounds per square inch.
   From observation corrected for calibration error.
3. Popping pressure in boiler drum, pounds ÷ square inch.
   From observation corrected for calibration error.
4. Average popping pressure, pounds per square inch gage.
   Average values of items 2 and 3.

5. Average popping pressure, pounds per square inch absolute.
   Item 8 + 14.7 pounds.
6. Closing pressure under valve, pounds per square inch gage.
   From observation corrected for calibration error.
7. Closing pressure in boiler drum, pounds ÷ inch gage.
   From observation corrected for calibration error.
8. Average closing pressure, pounds ÷ square inch gage.
   Average of items 6 and 7.
9. Average blow down, pounds ÷ square inch.
   Item 5 — item 8.
10. Average maximum lift, inches.
    From observation corrected for zero setting error.
11. Average lift at closing, inches.
    From observation corrected for zero setting error.
12. Area of opening at maximum lift, inches.
    From formula

$$A = \pi DL \frac{2\sqrt{R^2 - \frac{D^2}{4}} - L}{2\sqrt{R^2 + L^2 - 2L\sqrt{R^2 - \frac{D^2}{4}}}},$$

in which L = lift of valve in inches, item 14.
D = contact diameter between feather and seat.
R = radius of balled seat in inches.
A = opening area in square inches.

13. Theoretical discharge in pounds per hour.
    From formula

$$W = 3{,}600\frac{AP}{70},$$

in which W = discharge of dry steam in pounds per hour.
A = area of opening in square inches, item 12.
P = absolute steam pressure in pounds per square inch, item 5.

14. Correction factor from capacity runs.
Value assumed from measurement of discharge.
15. Probable actual discharge, pounds per hour, item 13 × item 14.

Directly before and after the capacity runs the above items are again observed and tabulated. During the capacity runs the following additional data is observed:

16. Valve casing pressure.
17. Calorimeter pressure, inches of mercury.
From observation.
18. Calorimeter temperature, degrees F.
From observation.
19. Steam quality.
From formula

$$x = \frac{h + k\,(t_s - t) - q}{r},$$

in which x = dryness fraction.
r = latent heat, and
q = heat of the liquid at the blowing pressure.
h = total heat.
t = temperature corresponding to the pressure in the calorimeter.
t_s = temperature in the calorimeter.
k = proper value of the specific heat of the steam in the calorimeter.

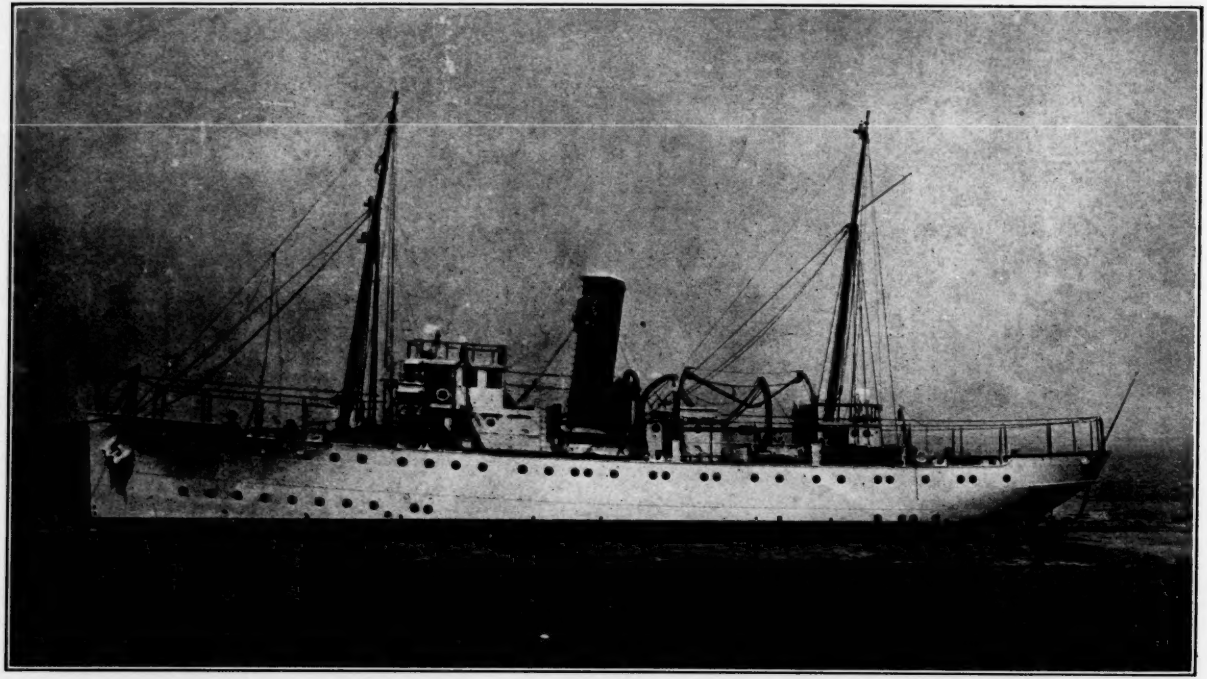
20. Lift of valve, inches.
From observation.
21. Water fed to boiler, pounds.

From observation of change of water level in feed tank, corrected for change of water level in boiler drum and for calorimeter discharge.

22. Steam discharged by safety valve, pounds per hour.
Item 21 × item 19, divided by number of hours of test.

23. Correction factor.
Item 22 ÷ item 13.

16. In addition to the above data the report includes the result of the spring tests, with the calculations as previously explained, and with curves of deflection, of which the attached curve is characteristic.



COAST GUARD CUTTER "OSSIPEE."

TRIALS OF COAST GUARD CUTTERS *OSSIPEE* AND *TALLAPOOSA*.

By SECOND LIEUTENANT OF ENGINEERS W. M. PRALL, U. S. C. G., MEMBER.

An Act of Congress, approved June 24, 1914, authorized the construction of two Coast Guard cutters, one for duty on the coast of Maine, replacing the cutter *Woodbury*, and one for duty in the Gulf of Mexico, replacing the cutter *Winona*, these two vessels being old and no longer fit for service.

In determining the size, type and power of the new cutters, Coast Guard Headquarters, after carefully considering the work which these ships would be required to perform, and the available appropriation, designed single-screw steel vessels somewhat smaller than the average sea-going cutter, having full lines, moderate power, and sufficient capacity for fuel and stores to insure keeping the seas for long periods, this latter quality being of great importance when searching for derelicts. Seaworthiness, reliability and ability to render efficient aid to vessels in distress, regardless of weather conditions, received first consideration; speed being a matter of secondary importance.

On September 15, 1914, contracts for building the ships were awarded to the Newport News Shipbuilding and Dry Dock Company of Newport News, Virginia, at their bid of $198,000 each. Keels were laid November 17, 1914, and the vessels launched on May 1, 1915. During construction the ships were designated as Coast Guard Cutters Nos. 26 and 27. No. 26, for duty on the Maine coast, was christened *Ossipee*; No. 27, for duty in the Gulf of Mexico, was christened *Tallapoosa*.

Standardization and full-power speed trials of the *Ossipee* were run on June 22, 1915; trials of the *Tallapoosa* were run on June 29, 1915, both trials being successful in every respect.

On July 8th and 15th, 1915, respectively, the ships were accepted by the Government.

PRINCIPAL HULL DIMENSIONS.

Length between perpendiculars, feet and inches	165–10
on L.W.L., feet and inches	150–00
Breadth, moulded, feet and inches	32–00
Depth, moulded, at side, feet and inches	20–09
Draught to L.W.L., feet and inches	11–06
Displacement at above draught, tons	908
Tons per inch immersion at L.W.L.	8.4
Block coefficient	.58

The two vessels are built to the same lines except that the forward underwater body of the *Ossipee* is modified by cutting away the forefoot, this being done to enable the vessel to better cope with the winter ice conditions which will be encountered on the Maine coast. This vessel is equipped for burning coal, but, because of the low price and facility with which oil fuel can be obtained at ports on the Gulf coast, it was deemed advantageous to fit the *Tallapoosa* as an oil burner. On this vessel is also installed an Audiffren-Singrun refrigerating apparatus, which is omitted on the *Ossipee*. These features constitute the only differences in the two ships.

The vessels are of the flush-deck type, with berth deck forward and aft. There are seven watertight bulkheads, two pole masts, schooner rigged, and one funnel.

DESCRIPTION OF MACHINERY.

The main engine is of the vertical, inverted, three-cylinder, triple-expansion type, arranged with high-pressure cylinder forward and low-pressure cylinder aft. All main valves are of the piston type worked by Stephenson link motions.

The main condenser is cylindrical with cooling surface of 1,328 square feet. The main circulating pump is independent and of the centrifugal type. The main air pump and two bilge pumps are attached and operated from the crosshead of the low-pressure cylinder.

The principal details of machinery are as follows:

Main engine, H.P. cylinder, diameter, inches	17
valve, diameter, inches	8
M.P. cylinder, diameter, inches	27
valve, diameter, inches	14
L.P. cylinder, diameter, inches	44
valves (two), diameter, inches	14
stroke of pistons, inches	30
travel of valves, inches	5½
diameter of main steam pipe, inches	6
exhaust pipe at engine, inches	15
condenser, inches	16
Crank shaft, built-up, length overall, feet and inches	14–7¾
diameter, main journals, inches	8¾
crank pins (two-inch hole), inches	8¾
length, first five main journals, inches	10
after main journal, inches	12
crank pins, inches	9
Thrust shaft, length overall, feet and inches	10–1½
diameter, inches	8¾
number of thrust collars, inches	8
diameter of collars, inches	17
thickness of collars, inches	1¾
length of steady bearings (two), inches	9
Intermediate shaft, length over-all, feet and inches	12–8
diameter, inches	8½
length of spring bearing, inches	11
Propeller shaft, length overall, feet and inches	15–2
diameter, inches	9½
length of forward bearing, feet and inches	2–0
after bearing, feet and inches	3–0
thickness of composition casing, forward bearing, inch	0 13/16
thickness of composition casing, after bearing, inch	0¾
composition casing, after bearing, inch	0⅝
All shaft couplings, diameter of discs, inches	18
thickness of discs, inches	2½
Boilers, Babcock & Wilcox, marine type, water tube, number	2
length of generating tubes (exposed), feet and inches	9–0
diameter of generating tubes (lower row), inches	4
(all others), inches	2
height over casing, feet and inches	10–2½
width over casing, feet and inches	11–4½
diameter of drum, inches	42
heating surface (each boiler), square feet	2,250
grate surface (each boiler), *Ossipee*, square feet	62

Smoke pipe, common to both boilers, diameter inside, feet and inches.	4–11
diameter outer casing, feet and inches..	5–9½
height above grates, feet and inches	47–0
Propeller, built-up, manganese bronze, four blade, R. H., diameter, feet and inches	9–6
pitch, feet and inches	12–0
developed area, square feet	39.1
Condenser, cylindrical, cast-iron shell, diameter inside, feet and ins..	3–6
length between tube sheets, feet and inches	7–3⅝
diameter of tubes (No. 18 U. S. S. G.), inch	0⅝
number of tubes	1,112
cooling surface, square feet	1,328
Circulating pump, centrifugal, diameter of suction, inches	8
diameter of impeller, inches	32
engine cylinder, inches	5
stroke of engine piston, inches	6
Feed-water heater, Griscom-Russell multicoil, diameter of shell, ins..	16½
length of shell, feet and inches	5–4½
number of coils	8
Evaporator, Griscom-Russell multicoil, diameter of shell, inches	30
length of shell, feet and inches	6–6
number of coils	8
capacity, gallons per 24 hours	2,300
Distiller, Griscom-Russell multicoil, diameter of shell, inches	10
length of shell, feet and inches	4–3
number of coils	2
Steam steering engine, manufactured by Hyde Windlass Company:	
Diameter of cylinders (two), inches	5
Stroke of pistons, inches	5½
Windlass engine, manufactured by Hyde Windlass Company:	
Diameter of cylinders (two), inches	6
Stroke of pistons, inches	8
Gypsy engine (located aft) manufactured by Hyde Windlass Company:	
Diameter of cylinders (two), inches	5
Stroke of pistons, inches	8

The electrical installation consists of twin sets of Westinghouse direct-current, compound-wound generators, turbine driven through reduction gear.

Capacity (each generating set), kw	15
Voltage	110
R.p.m., turbine	7,200
R.p.m., generator	1,800

The radio apparatus, manufactured by the Marconi Wireless Telegraph Company of America, consists of a main set of

2-kw. capacity and an auxiliary set of one-half-kw. capacity, which can be operated either by storage battery or the ship's main generators. Each vessel also carries a ¼-kw. portable radio set made by the Wireless Specialty Apparatus Company. The portable sets are operated by hand-power generators.

FUEL AND WATER CAPACITIES.

Coal bunker capacity, *Ossipee*, tons, ... 213
Fuel-oil capacity, *Tallapoosa*, gallons, . . . 53,200
Fresh-water capacity (for all purposes), *Ossipee*, gals.. 11,845
Fresh-water capacity (for all purposes), *Tallapoosa*, gallons, ... 13,345

RECIPROCATING PUMPS.

Number.	Make and Type.	Purpose.	Diameter steam cylinders, inches.	Diameter water or air cyls., inches.	Stroke, inches.
1	N. N. S. & D. D. Co., vertical, single acting, attached.	Main air.....	...	20	11
1	Blake & Knowles, vertical, simplex, double acting.	Main feed.....	10	6	12
1	Blake & Knowles, vertical, simplex, double acting.	Fire & Wrecking, also aux. feed.	18	10	18
2	N. N. S. & D. D. Co., vertical, single acting, attached.	Bilge.....	...	3½	11
1	Blake & Knowles, horizontal, duplex.	General service.....	7½	6	10
1	Blake & Knowles, vertical, simplex.	Fresh water.....	3½	4	4
1	N. N. S. & D. D. Co., double acting.	Hand deck.....	...	5	...
1	Warren, horizontal, duplex.	Oil fuel supply..... *Tallapoosa* only.	5½	6	6
2	Warren, horizontal, duplex.	Oil fuel service..... *Tallapoosa* only.	4½	2¾	4

TRIALS.

As engines practically identical with those described above have been installed and proved satisfactory in cutters previously built, and as the qualities of Babcock & Wilcox

STANDARDIZATION TRIALS, U. S. COAST GUARD CUTTERS.

Number of run.	*Ossipee*, July 22, 1915.						*Tallapoosa*, July 29, 1915.					
	Speed, knots.	R.P.M.	I.H.P.	Means. Kts.	Means. R.P.M.	Means. I.H.P.	Speed, knots.	R.P.M.	I.H.P.	Means. Kts.	Means. R.P.M.	Means. I.H.P.
1	7.63	55.29	77.2	6.27	56.55	78.8	6.27	51.32	68.4	5.63	52.39	76.5
2	4.58	55.89	77.0				4.65	52.37	79.7			
3	8.29	59.13	84.2				6.96	53.57	78.2			
4	7.35	82.77	217.1	9.03	84.51	237.4	7.45	82.12	240	8.80	83.02	250.8
5	10.52	84.95	240.4				10.12	83.15	256			
6	7.72	85.38	251.8				7.50	83.65	251			
7	11.69	98.42	407.9	10.29	98.25	403.0	8.91	97.14	397	10.28	97.40	405.3
8	8.90	97.54	398.0				11.53	97.03	405			
9	11.66	99.49	....				9.16	98.41	414			
10	9.98	107.96	569.0	11.12	108.41	590.0	12.37	108.30	568	11.23	108.93	581.3
11	12.15	108.70	604.0				10.08	108.98	593			
12	10.21	108.27	583.0				12.37	109.47	571			
13	11.80	130.0	1,049	12.38	129.81	1,050	11.73	127.9	954	12.47	129.65	1,024.3
14	12.87	130.67	....				13.00	129.59	1,037			
15	11.98	127.90	1,051				12.13	131.6	1,063			

U. S. Coast Guard Cutters.

TWO-HOUR FULL-POWER TRIALS UNDERWAY.

(Run in Hampton Roads and Chesapeake Bay.)

	Ossipee.	*Tallapoosa.*
Date of trial	6/22/15	6/29/15
Mean draught, feet and inches	10-4½	9-11½
Displacement, tons	785	748
Boilers in use	2	2
Heating surface	4,500	4,500
Grate surface	124	.....
Draft, natural	.18	.21
R.p.m.	133.9	134.0
Pressures :		
Boiler, gage	180	172
H.P. chest	169	164
First receiver	64.8	60.0
Second receiver	11.2	9.0
Vacuum	27.5	27.8
M.E.P. — H.P. cylinder	76.2	76.7
M.E.P. — M.P. cyinder	36.2	35.9
M.E.P. — L. P. cylinder	13.9	11.8
M.E.P. referred to L.P	39.0	36.8
I.H.P. — H.P. cylinder	349.4	351.7
I.H.P. — M.P. cylinder	419.2	415.5
I.H.P. — L.P. cylinder	426.4	363.8
I.H.P. — total	1,195.0	1,131.0
Speed in knots	12.55	12.66
Temperatures :		
Outside air	96	86
Working platform, E.R.	99	99
Fireroom	129	107
Stack	521	430
Main injection water	73	74
Outboard delivery	105	109
Main feed	186	184
Flue gas analysis :		
Per cent. CO_2	13.5	14.3
Per cent, O	3.7	2.2
Per cent. CO	0.7	0.08
Fuel	New River coal.	Texas oil.
B.t.u	.....	18,792
Flash (degrees F.)	.....	221
Specific gravity	.....	0.907

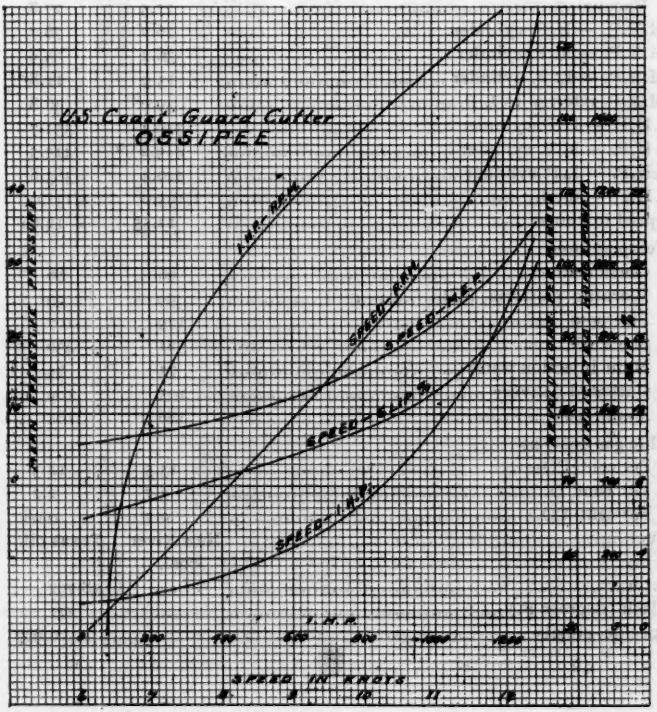
boilers have been well tested by actual service on vessels of the Coast Guard, the only trial requirements were as follows:

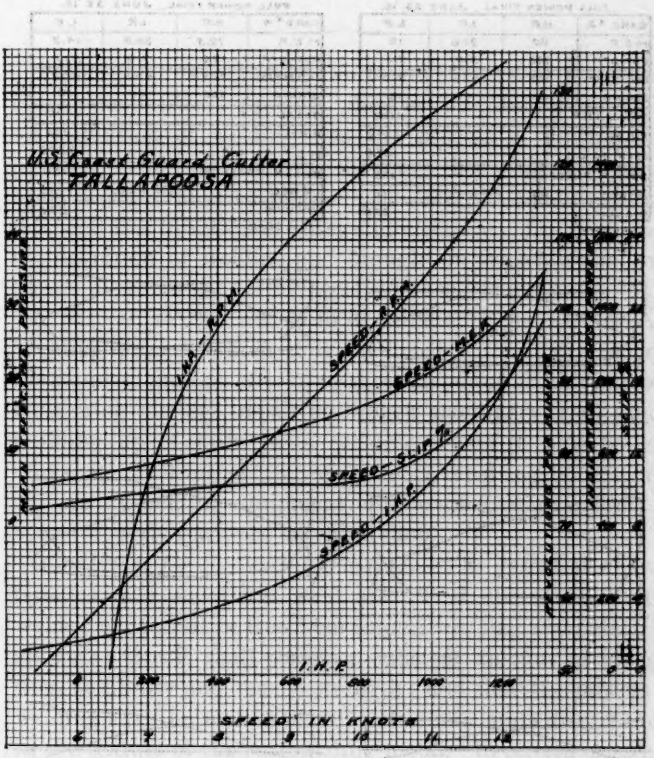
(*a*) An official dock trial consisting of the operation of the machinery at the dock until it could be run at full power for four consecutive hours without heating of bearings or necessity for adjustments.

(*b*) Standardization trials, run between six knots and full speed to determine the relation between revolutions, indicated horsepower and speed.

(*c*) A full-power trial, consisting of a run underway for two consecutive hours, working off at 180 pounds pressure all the steam which the boilers would generate under natural draft.

Results of the underway trials are shown in the accompanying curves and tables.



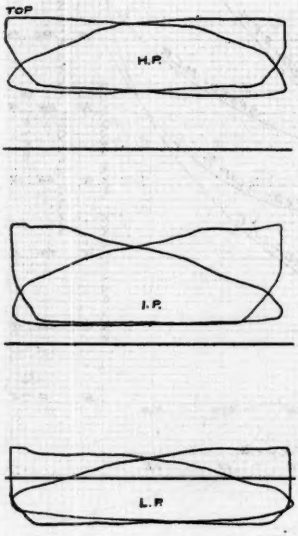

U.S. Coast Guard Cutter
TALLAPOOSA
I.H.P.
SPEED IN KNOTS

TALLAPOOSA.

FULL POWER TRIAL, JUNE 23 '15.

CARD #2	H.P.	I.P.	L.P.
M.E.P.	80	37.6	12
CUT-OFF	.722	.718	.715
I.H.P. PER CYL.	362	435	370
SPRING	100	40	16
TOTAL I.H.P.			1167
R.P.M.			134½
M.E.P. TO L.P.			37.6
BOILER PRESSURE			173
1ST REC.	63	2ND REC.	10
VACUUM			27.8

FULL GEAR.

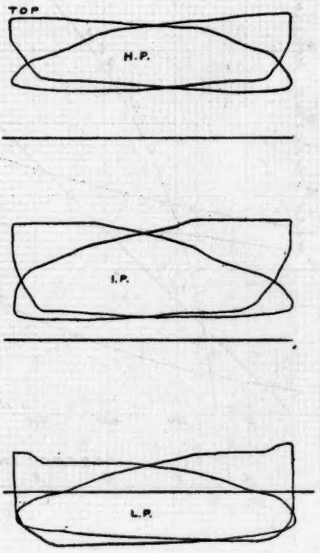


OSSIPEE.

FULL POWER TRIAL, JUNE 22 '15.

CARD #4	H.P.	I.P.	L.P.
M.E.P.	72.5	38.8	14.8
CUT-OFF	.722	.718	.715
I.H.P. PER CYL.	529	450	459
SPRING	100	40	16
TOTAL I.H.P.			1238
R.P.M.			135
M.E.P. TO L.P.			33.75
BOILER PRESSURE			180
1ST REC.	71	2ND REC.	13
VACUUM			27.5

FULL GEAR.



ELECTRIC-ARC WELDING.

By LIEUTENANT C. S. MCDOWELL, U. S. NAVY, MEMBER.

Welding is the joining of two pieces of metal of like or unlike characteristics by fusion, while in the plastic state. The old definition of welding was the process of uniting two pieces of metal by hammering them together while hot enough to be plastic. Modern methods, however, of obtaining high temperatures by means of gases and electricity, has broadened the definition of welding and brought in use additional processes, to which the term "welding" has been applied. It is the purpose in this article to describe only the Electric-Arc Welding process, which it is predicted will rapidly become the standard method of joining sheet metals of all thicknesses, reclaiming castings, repairing broken machinery of all kinds, building up of worn parts, welding seams in new boilers, tanks, etc., making of high-speed tools, repairing boilers, etc., and an arc-welding equipment will be a necessary adjunct to every properly-equipped machine shop.

Conditions for Successful Welding.—The essential characteristics of a successful weld are: That the metal in the welded joint shall be free from impurities, slag and defects of all sorts; that it shall possess a sufficient amount of elongation, flexibility and tensile strength; and that the process of welding shall be such as to reduce to a minimum disturbances in the texture of the surrounding metal. In certain classes of work flexibility and elongation in the weld is of more importance than tensile strength.

The quality of the weld obtained with electric welding is dependent on the folowing:

1st. The furnishing of the correct amount of energy at the weld for obtaining of the proper working temperatures of the material to be welded.

2d. The quality of the metal electrodes (the welding wire).

3d. The skill of the operator.

The Correct Amount of Energy.—The material worked on, the anode, is heated by the impinging of the cathode stream, by the julean heat developed by the ohmic contact resistance and by the radiant heat given off by the arc; the metallic pencil or cathode is heated by the julean heat due to its ohmic resistance to current flowing and by the slight contact resistance at the electrode surface. The greater proportion of the heat generated at the arc is at the anode, or material being welded (approximately 75 per cent. of the total heat), when the metallic arc is used. This is quite satisfactory due to the greater means of dissipation at the anode by radiation, convection and conduction. Practically all the energy supplied to the arc is dissipated as heat, only a slight proportion being given off as light, and to regulate the amount of heat units and thereby the temperature of a particular shape and class of material, it is essential to regulate the amount of energy supplied to the arc as measured in watts. The maximum temperature of steel in the usual converter is approximately 1,800 degrees C., the melting point being approximately 1,400 degrees C., the temperature of boiling steel at atmospheric pressure is approximately 2,450 degrees C., while the temperature of the arc stream may greatly exceed this. The result is that in electric-arc welding steel is being worked near a critical temperature. The material to be welded should be in a plastic state sufficient for the proper intermixing of the metal and obtaining of perfect fusion; if the temperature is too low the added material will not adhere to the original metal and the weld will fall apart at the surface; on the other hand, if too high a temperature is obtained the metal will be burnt and the weld will be greatly weakened by slag thus formed and will be of coarse and irregular structures. The surfaces of the metals to be welded must tend to cohere to a marked extent and the working temperature must be that at which the foregoing condition is most prominent. The best welding condition for iron and steel exists within a limited range

of temperature only. The safe working temperature depends somewhat on the material to be welded; an operator quickly obtains the necessary experience to tell if he has the proper temperature. The amount of energy necessary to obtain the proper temperature at the weld depends upon the size and shape of the piece worked on, it being the amount of energy necessary to supply the heat losses and keep the weld constantly at the proper welding temperature, the amount of energy required varies as the whole mass of the article becomes heated, a greater amount being required at first when the mass is cold; for this reason it is important in order to obtain consistent results to have a control of the energy at the operator's end of the line. This control should require very few changes in the supplied energy and is not to overcome the variation of energy due to changes in arc length. The temperature at the weld should remain practically constant; a momentary inrush of current will burn the metal at that point and cause a flaw with the chances of reducing the tensile strength of the weld 50 per cent. or even more.

Electrodes.—There are two methods of electric-arc welding: one, the Benardes process, in which a carbon electrode is used; and the other, the Slavinoff process, in which the metallic electrode is used. As a result of the tests which have been conducted, and from the experience of others in electric-arc welding, it is believed that the carbon-electrode process is not suited for general work, some of the reasons being that much greater difficulty is experienced in maintaining the proper temperature, and there are more chances of getting an excess of carbon in the weld. In the Slavinoff process, which is nearly universally used at present, it is necessary to have the metal electrodes of such material that the deposited metal in the weld shall have practically the same characteristics as the rest of the metal of the object worked on. As certain of the constituents of the electrode are partially lost in the arc, it is usually necessary to have the electrode contain an excess of certain materials over what is desired in the finished weld. The amount of the loss of these constituents depends upon the

temperature, and it is necessary in order to obtain desired and consistent characteristics in the finished weld to have a constant temperature at the weld. The steel companies will guarantee the results with the electrodes which they supply only if the system of arc welding with which they are used can maintain a constant temperature at the weld.

The Operator.—A certain amount of skill and experience is required of the operator, no matter what system of electric welding may be used; but some types of outfits require much more skill and closer attention than others, and it is considered essential that the ideal system should require a minimum of experience and only normal mechanical skill. A system which depends primarily on the skill of the operator cannot turn out consistent work and is not suited to the Navy's use.

Fluxes.—Certain companies claim that a flux is necessary to obtain good results, but in the tests conducted all sorts of material and in all positions have been welded, and the best results have been obtained from systems in which no flux is used. The claims in favor of the flux are: that it blankets the weld by forming a gas around the material which prevents oxygen reaching it and thereby prevents oxidation; this has been proven not necessary, by making similar welds first where oxygen was entirely excluded, and then under normal conditions in the air, and there was no difference in strength or structure of the weld. Another claim is that the flux acts as a scavenger to remove impurities from the weld; it cannot act in this way unless the metal actually boils, and this is a condition which, as previously shown, should be avoided. There are also certain users who believe a flux necessary for overhead work; but, in tests conducted, as good and consistent welds were obtained when welding overhead without a flux as in any other position. It is considered that in a good electrical welding system a flux is not necessary, and is simply an added expense and complication.

Automatic Control.—While it is recognized that it is desirable to have as simple an equipment as possible, it is considered necessary to have an automatic control of the input

energy to the weld, the reasons for which have been previously mentioned, so that when the proper amount of energy has been determined for a particular job it will remain constant regardless of the varying of the arc length. A system with fixed resistances depends entirely on the skill of the operator in maintaining his arc length constant and thereby the energy constant. This system gives good results at times, but our tests showed that even with a skilled operator, furnished by the manufacturer, tensile strengths varying as much as 50 per cent. on the same class of material were obtained. It should be possible for the operator to set the current controller at the desired amount as well as at the panel board; the controller should automatically keep the current approximately at the fixed value. A variation of less than 5 per cent. can be obtained with a well designed equipment.

Cutting.—The electric arc has been found suitable for cutting, but a carbon electrode must be used; no automatic-current control is necessary, although a choke coil is advisable to prevent large inrushes of current. The amount of current varies with the size of the material to be cut; from 250 to 400 ampères are required for burning off rivet heads and light section plates, while from 500 to 800 ampères may be required on plates 4 inches thick. This is a momentary load, however, and a 300-ampère continuous-duty machine is considered sufficient. It is necessary to cut away the edges of the cut and remove the burnt metal.

Preparation of Material to be Welded.—The material to be welded should be cleaned with a scraper or wire brush to remove oxides and prevent forming of slag, and it is also necessary to bevel the edge sufficiently so that the distance from the electrode to bottom of the weld is less than that of the electrode to any other part of the article, so that the arc will not stray. In thick plates, where possible, and especially in castings, it is usual to weld from both sides, and in this case the original material is pointed by beveling on both sides.

Application of Arc Welding.—During the past year the New

York Navy Yard has had contract electric welding done on boilers of various ships. Certain defective castings have been welded, blow holes filled in others, and miscellaneous repair work has been done while the various machines were under test. Additional uses are being developed as the advantages of this method became better known. A large saving in cost over other methods of repair have been made on boiler jobs, in addition to a saving in time, notwithstanding the large profit which the outside contractors have made on the jobs. A specific application of arc welding is in the making of high-speed tools, a piece of the tool being made of ordinary steel and high-speed tool steel is used for the cutting edge only. This is shown in detail later in this paper.

Some of the various applications are as follows:

Building up of worn wearing parts, pins, rollers, bearings, etc.
Welding of plates in lieu of riveting, or where seams are leaking.
Building up of rivets.
Building up stripped gears.
Repair of cracked castings.
Making of high-speed tools.
Filling blow holes.

In manufacturing work:

Welding of heads on tanks.
Welding of tubes in tube sheets.
Welding of feet and end frames, etc.

Brass, bronzes, and aluminum as well as steel, cast steel, wrought iron and cast iron can be welded, but none of the demonstrators have been able as yet to get very high tensile strength on naval brass.

Special Application for the Navy.—Electric-arc welding is considered especially applicable for use on shipboard for emergency repairs of all sorts. In this connection it may be noted that the British cruiser *Glasgow* put into Rio de Janeiro

after the battle off Chile with several holes below or near the water line, and was able, with an arc-welding set which happened to be in Rio de Janiero, to weld plates over the holes inside of 24 hours and put to sea, taking with them the arc-welding set.

Specific Cases Showing Costs and Savings.—Accurate cost and time data on some specific cases of a widely varying nature have been obtained from one of the large railroad companies. Photographs of the article before and after welding are given, with the times and cost to make the repairs, as compared to other methods.

Figure 1 shows electric welding being subjected to the following treatment:

A piece of boiler plate 18 by 20 inches was cut through the center and welded by the electric-welding process. This sheet was then used as a face and a tank built on the back side, as illustrated in the photograph.

This tank was filled with cold water and fuel-oil burner turned on the center of the weld in the boiler plate. The heat was so intense that the water was made to boil in an average of from 4 to 5 minutes.

This boiling process was continued for 10 minutes, then the water was allowed to cool down. When the water had become cool the burner was again put on sheet and water brought up to boiling point as before.

This operation was repeated nine times, the tenth time the boiling water was poured out and tank immediately filled with cold water and again raised to boiling point. This operation was repeated three times, after which the boiler plate was cut loose from the tank and test strips cut in the regular way.

The average tensile strength of nine strips from this plate was 55,000 pounds per square inch of welding metal.

Figures 2, 3 and 4 show cylinder on engine, class K–4, repaired by electric-welding process, thus saving the application of new cylinder.

The following statement shows cost to repair by above process as against applying new:

Cost of Present Method.

Labor:			
Removing old and applying new cylinder complete			$125.00
Machining cylinder complete			17.50
Cylinder bushing machined and applied			5.85
Valve-chamber bushing, machined and applied			5.40
Turning and fitting bolts and studs			7.00
Cost of transportation			9.00
Cost of loading and unloading and handling cylinder			12.00
			181.75
Material:			
Cylinder, weight 8,550 lbs., at 3 cents per lb.	$256.50		
Hunt-Spiller bushings	60.50		
Bolt and stud material	8.00		
Deduct for scrap value of old cylinder	42.00	$283.00	
Total net cost new cylinder			$464.75
Cost by Electric Welding:			
Labor:			
Preparing cylinder for welding	55.00		
Welding, 11¼ hours, at 27½ cents per hour	4.40		
		59.40	
Material:			
14 pounds of welding wire, at 5 cents per lb.	.70		
Electricity, 11¼ hours, at 12 cents per hour	1.38		
Bolt and stud material	2.00	4.08	63.48
Total net saving			401.27

Figures 5 and 6 show broken walking beam for air compressor repaired by electric welding for U. S. S. *Drayton*, Brooklyn Navy Yard.

Cost of New Walking Beam:			
Labor:			
Machining complete		$8.10	
Material:			
New casting	$12.00		
Deduct for scrap value of old castings	.60		
		11.40	
Net cost of new walking beam			$19.50
Cost to Electric Weld:			
Labor:			
Cutting out and preparing for weld, 3 hours, at 30 cents per hour	$0.90		
Welding, 2 hours, at 27½ cents per hour	.55		
Drilling, reaming and facing holes	.45		
		1.90	
Material:			
2¼ pounds welding wire, at 5 cents per lb.	.11		
Electricity, 2 hours, at 12 cents per hour	.24		
		.35	2.25
Net saving by electric welding			17.25

Figures 7 and 8 show lathe gears reclaimed by electric welding process.

Statement showing comparative cost to reclaim by above method as against purchasing new gears:

Cost of new 13-inch gears, shaft and pinion		$9.00	
Cost of new 11-inch gear		4.00	
Scrap value of old gears		.20	
Net cost new			12.80
Cost to Reclaim by Electric Welding:			
Labor:			
Welding, 5 hours, at 27½ cents per hour	$1.37		
Cutting teeth	2.80		
		4.17	
Material:			
3½ pounds of welding wire, at 5 cents per lb.	.17		
Electricity, 5 hours, at 12 cents per hour	.60	.77	4.94
Net saving by electric welding			7.86

Figure 9 shows broken jack standard taken from scrap pile and reclaimed by electric welding process.

Statement showing comparative cost of reclaiming one jack standard as against purchasing new:

Cost new		$4.00	
Scrap value of broken standard		.30	
Net cost new			$3.70
Cost to Reclaim by Electric Welding Process:			
Labor:			
¼ hour, at 27½ cents per hour	$0.20		
Redrilling holes	.10		
		$0.30	
Material:			
1 pound of welding wire, at 5 cents per lb.	.05		
Electricity, ¼ hour, at 12 cents per hour	.09		
		.14	.44
Net saving by electric welding			$3.26

Figures 10 and 11 show feed-water pump reclaimed by electric welding process.

Statement showing comparative cost to reclaim by electric welding as against purchasing new:

Cost of new cylinders machined, ready to set up		$220.00	
Deduct for scrap value		9.00	
Net cost of new pump exclusive of working parts			$211.00
Cost to Repair by Electric Welding:			
Labor:			
Welding, 8 hours, at 27½ cents per hour	$2.20		
Boring out and applying bushing where broken	6.00		
		$8.20	
Material:			
7 pounds of welding wire, at 5 cents per lb	.35		
Electricity, 8 hours, at 12 cents per hour	.96		
Brass bushing	1.75		
		3.06	
			11.26
Net saving by electric welding			199.74

Figure 12 shows wheel lathe cutting tool, 1½-inch by 3-inch by 16 inch, made from tire steel with high-speed cutting point attached by electric welding process.

Statement showing comparative cost of tool made by above mentioned as against tool made entirely of high-speed steel:

Tool Made from High-Speed Steel:			
Labor:			
Forging and finishing complete		$0.60	
Material:			
18 pounds high-speed steel at 55 cents per pound		9.90	$10.50
Tool Made from Tire Steel Having High-Speed Steel Point Attached:			
Labor:			
Forging tool and point complete	.55		
Electric welding on point	.15		
Dressing off	.08	.78	
Material:			
18 pounds tire steel at .5 cent per pound	.09		
¾ pound high-speed steel at 55 cents per pound	.41		
¼ pound welding wire at 5 cents per pound	.01		
Electricity, ¼ hour at 12 cents per kw. hour	.06	.57	1.35
Total initial saving			9.15

NOTE.—As this tool becomes shorter by grinding, new points will be required, and two points beside the first one applied will be necessary in order to get the same life as could be obtained from entire high-speed tool. These points are applied at a cost of .90 each for labor and material; thus the total final saving on tool amounts to $7.35

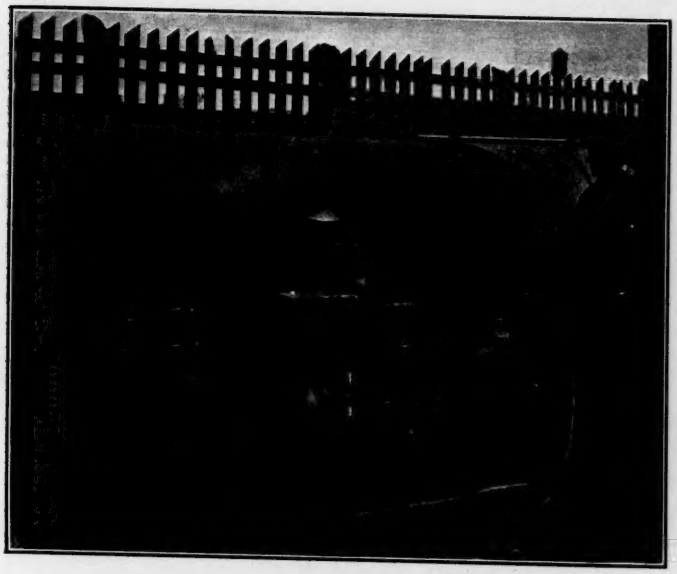


FIG. 1.

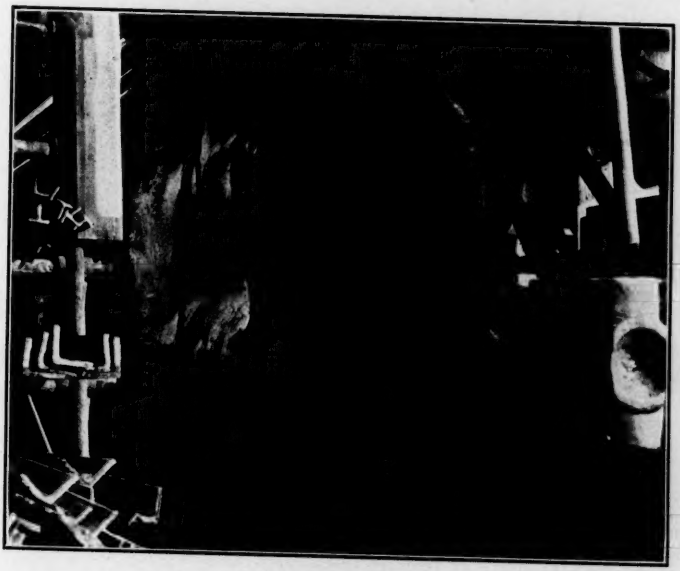


FIG. 2.

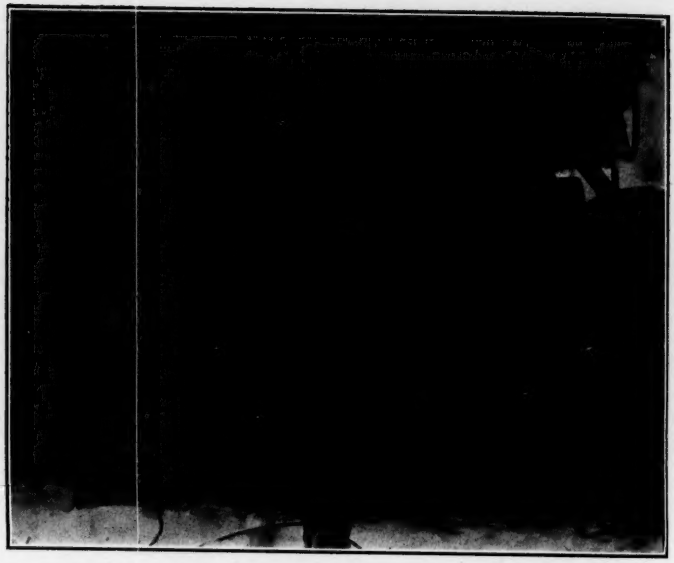


FIG. 3.

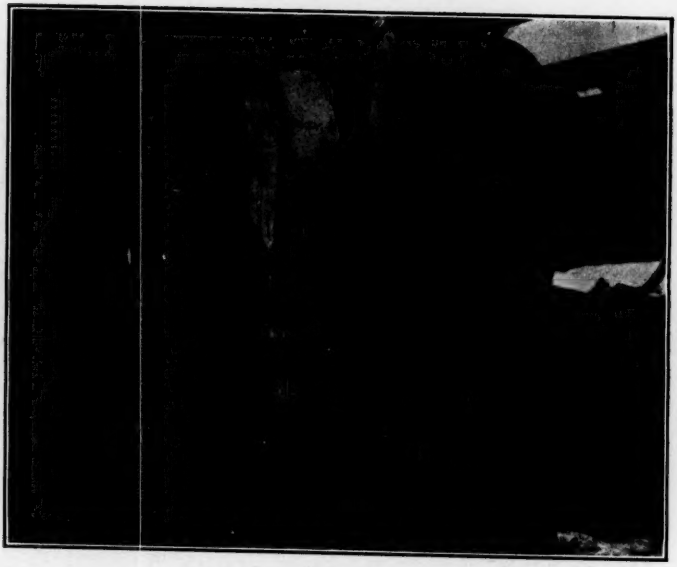


FIG. 4.

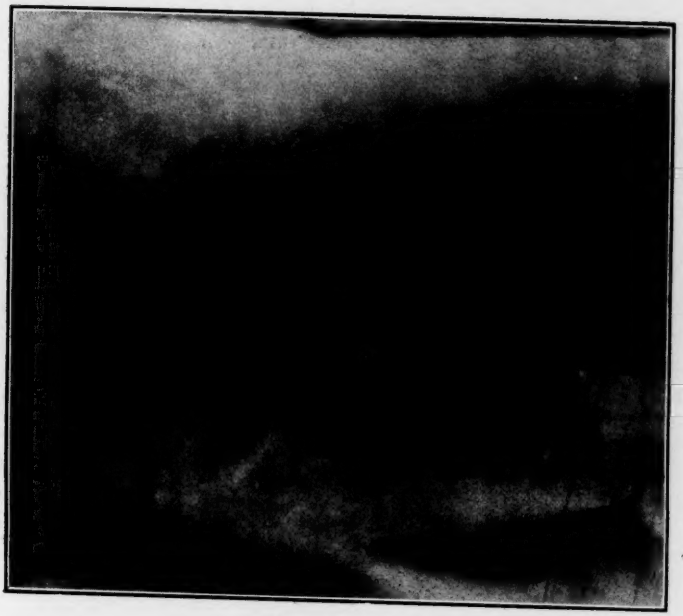


FIG. 5.

FIG. 6.

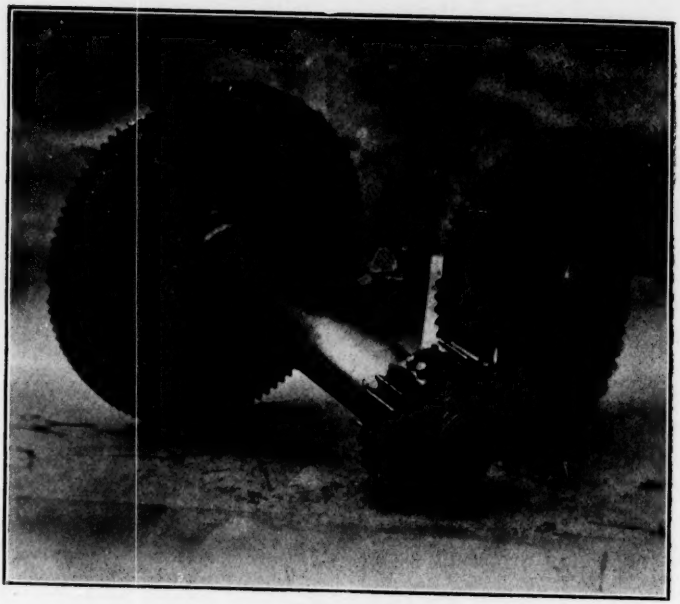


FIG. 7.

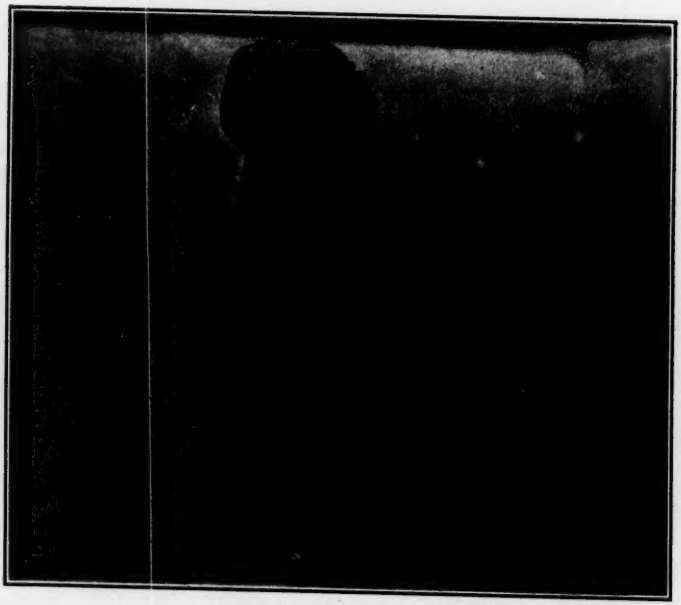


FIG. 8.

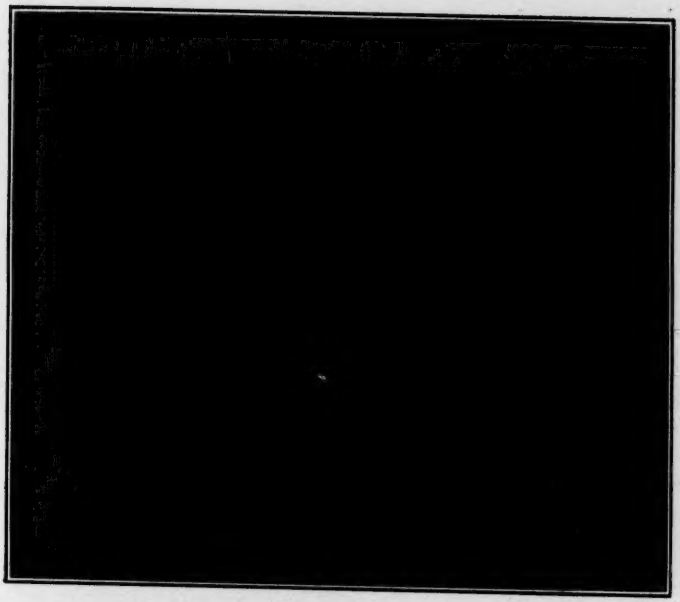


FIG 9.

FIG. 10.

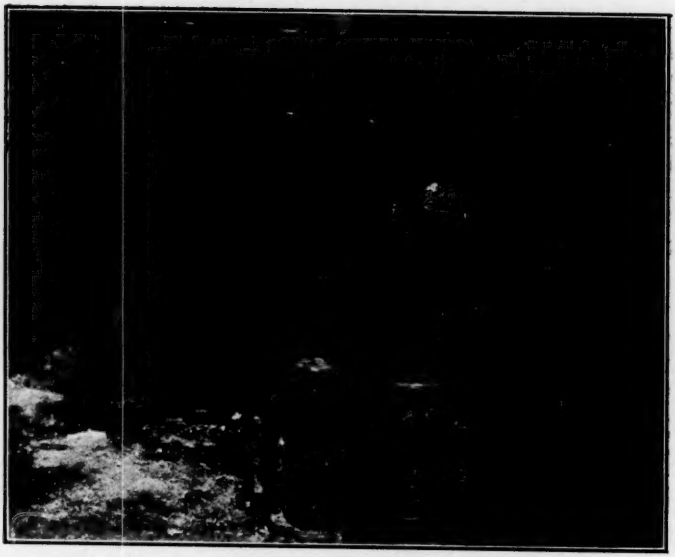


FIG. 11.

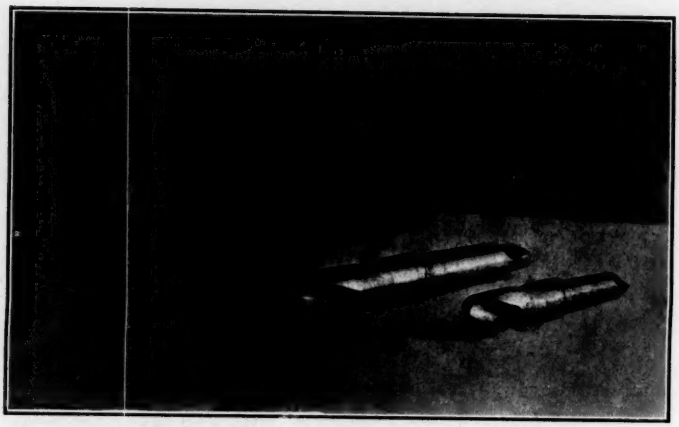


FIG. 12.

Short $2\frac{1}{16}$-inch carbon drill converted to high-speed drill by electric welding in an insert of high-speed steel at cutting edge.

It is estimated that the life of three inserts will be equal to that of a new carbon drill 12 inches in length.

Statement showing comparative costs:

One new $2\frac{1}{16}$-inch by 12-inch carbon drill			$4.50
Cost to apply High-Speed Insert to Old Drill:			
Labor:			
Preparing cutting edge for insert	$0.35		
Welding in insert	.10		
Dressing	.15	$0.60	
Material:			
2 ounces high-speed steel at 55 cents per pound	.07		
Welding wire	.01		
Electricity, $\frac{1}{3}$ hour at 12 cents per hour	.04	.12	
Total cost and labor and material		.72	
Three inserts			$2.16
Total saving by electric welding in inserts over cost of new drill			2.34

U. S. S. *WADSWORTH.*

DESCRIPTION AND TRIAL PERFORMANCE.

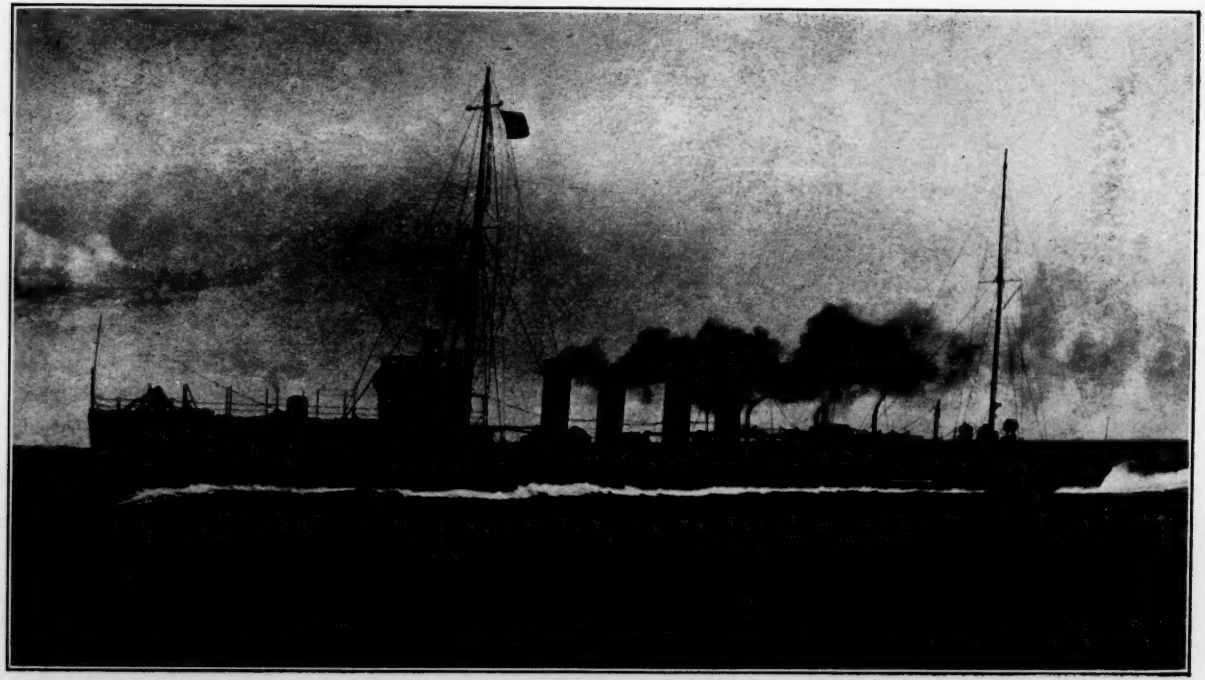
By Henderson B. Gregory, Associate.

The builders, Bath Iron Works, Limited, of Bath, Maine, have recently successfully completed the preliminary official trials of the U. S. S. *Wadsworth.*

Officially known as Torpedo Boat Destroyer No. 60, the *Wadsworth* is one of six boats authorized by an Act of Congress, approved March 4, 1913. The contract for her construction was signed October 15, 1913, the time of completion being twenty-four months and the price $884,000.00. She is a twin-screw vessel, driven by Parsons turbines, fitted with reduction gear, and designed for a speed of 30 knots, at a displacement of about 1,050 tons, with the turbines developing 17,500 shaft horsepower. Steam is supplied by four Normand water-tube boilers.

PRINCIPAL HULL DIMENSIONS.

Length between perpendiculars, feet and inches	310–0
on L.W.L., feet and inches	310–0
overall, feet and inches	315–3
Beam, extreme, feet and inches	30–6
on L.W.L., feet and inches	29–8½
Ratio of length to beam (L.W.L.)	10.446
Draught to L.W.L., mean, feet and inches	9–4½
Displacement corresponding, tons	1,050
per inch at L.W.L., tons	13.8
Area immersed midship section, square feet	210
L.W.L. plane, square feet	5,775
Wetted surface, square feet	10,000
Coefficient of fineness, block	0.44
midship section	0.75
L.W.L.	0.63



U. S. S. "WADSWORTH."

GENERAL DESCRIPTION OF HULL.

The vessel is of the customary raised-forecastle type. There are two masts, fitted with wireless, signal yards, etc., and four smoke pipes.

Forecastle Deck.—This deck, about 80 feet long, provides for the stowage of anchors, bow gun and pilot house. On top of the pilot house and extending to the vessel's sides is the bridge fitted with a steering wheel. Above the bridge is a searchlight platform, mounting a 30-inch searchlight.

Main Deck.—The main deck is continuous from stem to stern. Under the forecastle deck are the officers' quarters, pantry, galley, radio room, etc. Abaft the forecastle is a weather deck on which are located the battery, described elsewhere, and a deck house aft, containing the crew's toilet rooms, etc. On top of the deck house is a steering platform and a 30-inch searchlight.

Platform Deck.—This deck extends forward and aft of the machinery space only. Forward it contains the paint and oil room and crew's quarters, and aft are located crew's and petty officers' quarters, and steering gear.

Hold.—In the hold, forward and aft, are located trimming tanks, fuel-oil tanks, magazines and stores. The chain lockers are forward, and the machinery spaces occupy the entire mid-portion of the hold. A reserve feed tank is located in the forward engine room and fresh-water tanks in the forward fireroom, port and starboard. The engineer's store rooms are in the firerooms.

BATTERY.

There are four 4-inch rapid-fire guns in the battery, one on the forecastle, two on the main deck forward, port and starboard, at break of forecastle, and the other on the main-deck center line shaft of deck house.

The torpedo equipment consists of four 21-inch twin torpedo tubes mounted on the main deck, two port and two starboard.

There is a four-stage Ingersoll-Rand air compressor for

charging the torpedoes. It is located in forward engine room and has a capacity of 20 cubic feet of air at 2,500 pounds per square inch per minute. It is steam driven, the steam cylinder being 8 inches diameter and the compressor cylinders $9\frac{1}{4}$, $4\frac{3}{4}$, $3\frac{1}{8}$ and $1\frac{1}{4}$ inches diameter, respectively, for the four stages, with a common stroke of 5 inches. No accumulator is fitted.

BOATS CARRIED.

The following small boats are carried on skid beams above the main deck just abaft the midship frame. Davits are provided for launching the boats.

1 24-foot motor-sailing launch;
1 21-foot motor dory;
1 24-foot whaleboat;
1 14-foot wherry;
1 10-foot punt.

COMPLEMENT.

Commanding officer, . . .	1
Wardroom officers, . . .	4
Crew, ...	95
Total, ...	100

ANCHOR WINDLASS.

The windlass engine is located on the main deck just forward of the officers' quarters, with the capstan above on the forecastle. It is a double, vertical engine, made by the Hyde Steam Windlass Co., with cylinders 5 inches diameter by 4 inches stroke.

STEERING ENGINE AND GEAR.

The steering engine is of the Hyde Steam Windlass Company's double, vertical type, with steam cylinders $6\frac{1}{2}$ inches

diameter by 8 inches stroke. It is located on the platform deck in the steering-gear room aft.

In addition to the steam gear an emergency hand-steering gear is also provided in the steering-gear room.

FIRE MAIN.

The fire main extends throughout the machinery spaces on the port side close under the main deck beams. It is 3 inches outside diameter and is led forward and aft into the crew's quarters. The main is supplied by the three fire and bilge pumps and the oil-cooler circulating pump, as noted in Table I. Branches for the various fire plugs are taken off the main at convenient locations. All fire plugs are fitted for 1½-inch hose and are located as follows:

Plug No.	Location.
8, ...	Forecastle deck.
4 to 7 inclusive, . . .	Main deck.
1 and 3, ...	Platform deck.
2, ...	Forward fireroom.

In addition to the regular fire plugs above enumerated there is a 1½-inch hose valve on the discharge manifold of each fire and bilge pump.

Forward and aft there are 2½-inch connections from the fire main for magazine flooding and sprinkling.

A 1-inch connection is taken off the fire main aft for flushing out the stern-tube bearings, a full size branch being led to each bearing.

FLUSHING SYSTEM.

The flushing system is taken off the fire main direct. There is a 1½-inch connection forward supplying the officers' water closet and ship's galley, and one of 2½ inches aft for the crew's water closets and wash room.

FRESH-WATER SYSTEM.

Fresh water is carried in the ship's tanks, located in the forward fireroom, port and starboard. Each tank has a 2½-inch filling connection, fitted with hose valve at the ship's side. There is also a 2-inch filling connection from the distilling apparatus to each tank.

Located on the forecastle deck, immediately abaft the pilot house, is a small gravity tank for supplying the galley and officers' showers. The tank is fitted with steam coil to prevent freezing in cold weather. A hand pump is provided on main deck abaft the galley for filling this tank.

DRAINAGE SYSTEM.

A main drain is led throughout the machinery spaces and connected to the fire and bilge pumps by suctions the full size of the main. Macomb strainers are fitted in these suctions close to the pumps. The main is 4 inches outside diameter in the engine room and after fireroom, reducing to 2½ inches outside diameter in the forward fireroom. There are two full size bilge suction connections from the main drain in each fireroom and one in each engine room, fitted with plate strainers at the bilge ends.

For draining compartments outside of the machinery spaces there are 2½-inch outside diameter branches leading forward and aft and fitted with connections to the various compartments requiring drainage and the trimming tanks.

In addition to the drainage system proper, each engine room is provided with a 7-inch independent bilge-suction connection to the circulating pump for emergency use.

VENTILATION.

The officers' and crew's quarters are provided with a forced-ventilation system. There are two circuits, one forward and the other aft, each having a 2,500-cubic foot B. F.

Sturtevant fan, driven by a General Electric motor. All other spaces are ventilated by natural means, except the firerooms which, when closed, are ventilated by the forced-draft blowers.

HEATING SYSTEM.

The usual heating system, with brass-pipe coil radiators, is installed. Steam for the quarters forward is taken off the auxiliary steam line in the forward boiler room, and that for the after compartments from the auxiliary steam line in the engine room.

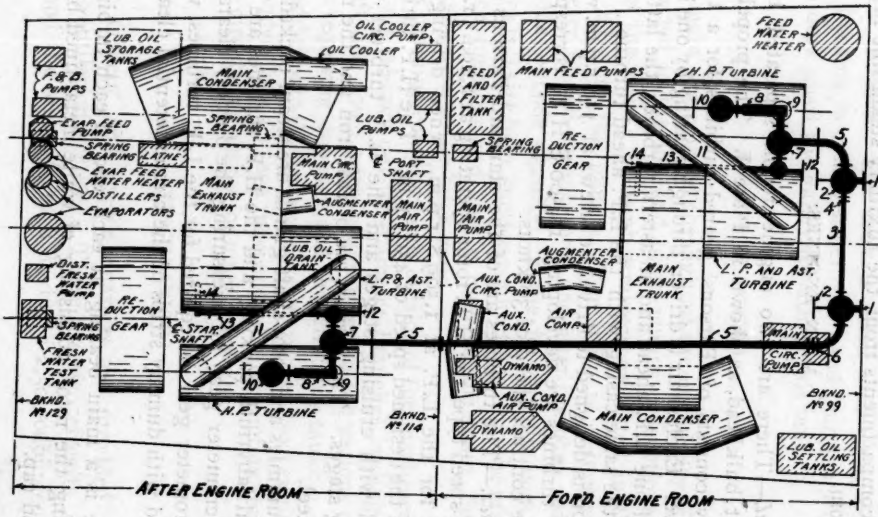
MAIN ENGINES.

General.—There are two engine rooms separated by a watertight bulkhead, as shown in Plate I. The propelling machinery consists of Parsons' geared turbines for a twin-screw drive. Each shaft is driven through gearing by one H.P. ahead and one L.P. ahead and an astern turbine; the latter is fitted in the same casing with the L.P. ahead turbine. The installation is designed to drive the screws at 450 r.p.m. when the main turbines are developing 17,500 S.H.P., corresponding to the contract speed of 30 knots.

Turbines.—The turbines are of the standard Parsons reaction high-speed type, the H.P. rotor operating at 2,494.5 r.p.m. and that for the L.P. at 1,509.8 r.p.m., when driving the screws at the designed speed of 450 r.p.m. The H.P. turbines are fitted with cruising stages and the L.P. turbines with reversing stages. The casings are of cast iron and the rotors forged steel.

The dummies and rotor-shaft glands are steam packed with the usual labyrinth packing, and the H.P. turbines are fitted with micrometer gear for measuring the dummy clearances. No micrometer gear is required for the L.P. turbines, which are fitted with dummy strips of the circumferential clearance type.

There is a main bearing at each end of each turbine for supporting the rotor, consisting of white metal-lined bottom brass and cap.



ITEM	DESCRIPTION
1	10⅜" O.D. MAIN STEAM FROM BOILERS.
2	9⅝" MAIN STEAM STOP VALVE
3	7⅝" O.D. MAIN STEAM CROSS-CONNECTION
4	EXPANSION JOINT
5	10⅜" O.D. MAIN STEAM TO H.P. TURBINE
6	EXPANSION JOINT
7	9⅝" H.P. TURBINE THROTTLE VALVE
8	MAIN STEAM STRAINER
9	9⅝" STEAM TO H.P. TURBINE CRUISING STAGES
10	9⅝" BY-PASS VALVE STEAM TO H.P. TURBINE 1st STAGE
11	20⅝" H.P. TURBINE EXHAUST TO L.P. TURBINE
12	6" ASTERN THROTTLE VALVE
13	6⅝" O.D. ASTERN STEAM
14	ASTERN STEAM STRAINER

PLATE I - U.S.S. WADSWORTH - ARRANGEMENT OF ENGINE ROOMS.

All turbines are provided with thrust blocks at the forward end, of the usual Parsons type. The lower half is arranged to take forward thrust and the upper half thrust in the opposite direction.

Main Turbine Data.

Rotor drums:	Diameter.	Length.
H.P., inches	20¾ and 21	81¾
L.P., inches	42	34⅜
Astern, inches	26	31 3/16
Number of expansions:		
H.P.	12 (4 cruising and 8 main.)	
L.P.	8	
Astern	5	
Turbine casing, diameter, each expansion:		
H.P. cruising, inches	22, 22¼, 22½ and 23	
main, inches	23, 23⅝, 24, 24⅝, 25¼, 26¼, 27½ and 29½	
L.P., inches	47, 48½, 49½, 51¾, 54, three of 59	
Astern, inches	27½, 29, 32, two of 38	
Length of casing for each expansion and diameter noted above:		
H.P. cruising, inches	7⅞, 7⅞, 8 7/16 and 10 1/16	
main, inches	5, 3¾, 5, 3 1/16, 5¼, 4⅞, 4¾ and 5 1/16	
L.P., inches	2½, 2½, 2⅝, 3⅝, 3⅝, 5 1/16, 6 3/16 and 5	
Astern, inches	4¾, 5¾, 5¼, 5 1/16 and 7 1/16	
Rows of blading for each expansion:		
H.P. cruising, each	9	
main	4, 3, 4, 3, 4, 3, 3 and 3	
L.P.	2, 2, 2, 2, 2, 3, 3 and 2	
Astern	4, 4, 3, 3 and 3	
Length of blades for each expansion:		
H.P. cruising, inches	⅝, ¾, 1 1/16 and 1½	
main, inches	1, 1 3/16, 1½, 1 1/16, 2¼, 2⅝, 3⅝ and 4½	
L.P., inches	2½, 3½, 3 7/16, 4⅞, 6, 8¼, 8½ and 8¼	
Astern, inches	¾, 1½, 3, 6 and 6	

Rotor shafts and bearings:	Length of bearing.	Diameter at bearing.	Diameter of axial hole.
H.P., inches	5½	6½	3
L.P., and astern, inches	6½	6½	3

Thrust bearings, each:	
Collars on shaft, number	13
Thickness, inch	0⅝
Distance between, inch	0 9/16
Outside diameter, inches	7½
Inside diameter, inches	5
Number of shoes, top	12
bottom	12

TURNING GEAR.

A hand-turning gear is provided for each line of shafting. Each comprises a plug, fitted to squared end of axial hole of reduction-gear pinion shaft, the external end of plug being also squared for reception of ratchet wrench. Both ratchet wrench and plug are readily disconnected when not in use.

LIFTING GEAR.

Efficient lifting gear is installed for the main turbines. The lifting mechanism is hand operated.

REDUCTION GEAR.

The reduction gears are after the Parsons' design. Each unit consists of two forged-steel pinions, forged integral with their shafts, driving a main gear. The main gear is secured to its shaft by bolts, two collars being provided on the shaft for the purpose. It is of the built-up type, consisting of a forged-steel rim securely bolted to two steel-plate discs, forming a wheel, the whole being cross-braced by a cast-steel cone fitted between the discs and through bolted with the after disc to the rim and with the forward disc to its shaft collar. The gear and pinions have helical cut teeth. The pinion shafts are direct connected to the turbines, the H.P. turbine driving the outboard pinion and the L.P. turbine the inboard pinion. The gear shaft is coupled direct to the main shafting, and on its forward end is fitted the main thrust bearing, of the Kingsbury pivoted type.* The gear box consists of a rigid cast-steel bedplate, supporting the bearings, thrust, etc., and securely bolted to foundations built in the vessel. The entire apparatus is inclosed in a sheet-steel casing and provided with an elaborate system of forced lubrication for the shaft bearings and spray nozzels for the gear and pinions.

Plate II is reproduced from a photograph, taken aboard the vessel, of the port reduction gear with upper casing removed.

* A complete description of this type thrust bearing, by Lt. W. W. Smith, U. S. N., Member, was published in vol. 24, page 1151, of the JOURNAL OF THE AMERICAN SOCIETY OF NAVAL ENGINEERS.

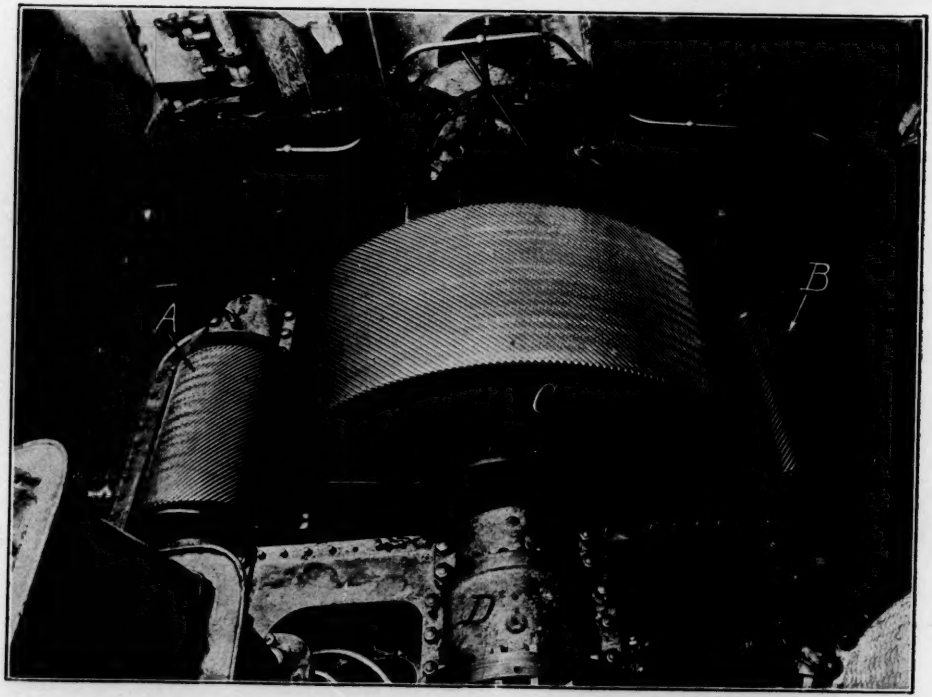


PLATE II.—PORT REDUCTION GEAR, LOOKING AFT. UPPER CASING REMOVED.

A. Inboard pinion, driven by L.P. turbine. *B*. Outboard pinion, driven by H.P. turbine.
C. Main gear. *D*. Thrust box. *E*. Main shaft.

Reduction Gear Data.

	Wheel.	H.P. pinion.	L.P. pinion.
No. of teeth	255	46	76
R.p.m.	450	2,494.5	1,509.8
Diameter pitch circle, inches	66.227	11.947	19.738
over teeth, inches	66.467	12.187	19.978
Pitch, circular, inches	.....	.8159	.....
diametral	.....	3.8504	.....
Spiral angle, degrees and minutes	.....	44–23.7	.....

SHAFTING.

The starboard shafting is in three sections, consisting of one line shaft, one stern-tube shaft and one propeller shaft. The port side has four sections, an additional section of line shaft being necessary for extension to the forward engine room.

There are two stern-tube and one strut bearings for each line of shafting. The bearings are lined with lignum vitae. The shafts are composition bushed at the bearings, and within the stern tubes are covered with a seamless-drawn brass-tube casing, shrunk on.

Each section of line shafting is supported by two spring bearings, white-metal lined, of the self-oiling type.

The inboard coupling consists of a collar secured to the stern-tube shaft by four keys. Forward of this collar are two thin half collars fitted into a groove turned in the end of the shaft, to prevent the shaft from backing out, the whole being through-bolted to the coupling disc on the line shaft.

The outboard coupling is of the ordinary sleeve type secured to the shaft by four feathers and two cross-keys each.

Shaft Data.

Line shafts, diameter, outside, inches	10¼
at journals, inches	10⅜
axial hole, inches	6¼
Stern-tube shaft, diameter, outside, inches	10¼
axial hole, inches	6¼
Propeller shafts, diameter, outside, inches	10¼
axial hole, inches	6¼

Coupling discs, diameter, inches	18
thickness, inches	2⅛
Inboard coupling, diameter of collar, outside, inches	18
inside, inches	11¼
length of collar, inches	7½
thickness of half collars, inches	1⅝
Coupling bolts, number each coupling	8
diameter (taper)* at face of coupling, inches	1 15/16
Outboard coupling, length of sleeve, inches	36¼
diameter of sleeve, outside, inches	14
Spring bearings, diameter, inches	10⅝
length, inches	14
Forward stern-tube bearings, diameter, inches	11½
length, inches	26½
After stern-tube and strut bearings, diameter, inches	11½
length, inches	48

PROPELLERS.

The propellers are three-bladed. The port propeller is left-hand and the starboard propeller is right-hand. The blades and hubs are of manganese bronze and cast in one piece. The blades are true-screw machined to pitch.

Propeller Data.

	Starb'd.	Port.
Diameter, feet, and inches	7–7.75	7–7.5
Pitch, feet and inches	8–7.58	8–7.35
Ratio of pitch to diameter	1.128	1.29
Area, projected, square feet	25.416	
helicoidal, square feet	29.541	
disc, square feet	46.163	
Ratio, projected, to disc	0.55	
helicoidal, to disc	0.64	

MAIN CONDENSING APPARATUS.

Main Condensers.—There is one main condenser of circular section in each engine room. They are of the curved-tube type, with the tubes expanded in both tube sheets. The principal dimensions are as follows:

* Parallel bolts for inboard coupling.

Diameter of shell, maximum, inside, feet and inches	5-8½
Thickness of shell, inch	0½
tube sheet, inches	1¼
Tubes, number	3,303
diameter, inch	0¾
thickness, inch	0.049
mean length between tube sheets, feet and inches	10-0
Cooling surface, square feet	5,404.5
Main exhaust nozzle, area through, square feet	18.4
Diameter of air-pump suction, inches	11
circulating-water inlet and outlet, inches	20
auxiliary exhaust nozzle, inches	6
bleeder, forward condenser only, inches	2½

The main air and circulating pumps and their connections are given in Table I.

Vacuum Augmenter.—A Parsons vacuum augmenter is provided for each main condenser, consisting of a small condenser of the curved-tube type, steam jet and water seal, all connected to the main condenser and air-pump suction piping in the usual manner.

Each augmenter condenser is of the following principal dimensions:

Diameter of shell, maximum, inside, inches	21
Thickness of shell, inch	$0\frac{3}{16}$
Tubes, number	224
diameter, inch	0¾
thickness, inch	0.049
Mean distance between tube sheets, inches	45.8
Cooling surface, square feet	139.6
Diameter of augmenter connection, inches	8
air-pump suction, inches	8
circulating-water inlet and outlet, inches	4

ENGINE-ROOM AUXILIARIES.

Pumps.—A complete list of the engine-room pumps and their connections is given in Table I.

Feed and Filter Tank.—A feed and filter tank of about 800 gallons gross capacity is located in the forward engine-room. The filter chamber is in the top of the tank, and so arranged that the entering water will flow over the top of a plate and

TABLE I - PUMPS AND CONNECTIONS - U.S.S. WADSWORTH.

No.	Pumps.	Size (Ins.)	Type	Suction Pipes From-	Ins.	Discharge Pipes To-	Ins.	Location
2	Main Air	(10)14 x (2) 28 x 18	Twin, Vertical, Bucket, Single-Acting, "Warren"	Condensers, through Water Seal Reserve Feed Tanks	11	Feed Tank	10	One in each Eng. Room
2	Aux. Circ for Main Condenser	10" diam Impeller	Turbine Driven, Centrifugal, "Worthington"	Sea Bilge	14 7	Main Condenser	14	Do
2	Main Feed	13x10x16	Vertical, Piston, Double-Acting, Single, "Warren"	Feed Suction Pipe and Reserve-Feed Tanks Water-Seal Cross-Connecting Pipe	5½	Main Feed Discharge	4	In Ford. Eng. Room.
2	Aux Feed	Do	Do	Feed Suction Pipe and Reserve-Feed Tanks Hose Connection	5½ 1½	Aux. Feed. Hose Connection	4 1½	One in each Boiler Room
2	Fire and Bilge	7x7x12	Do	Sea Drainage Bilge of Same Comp'y Hose Connection	4 4 4 1½	Fire Main Overboard Distiller Hose Connection	2½ 3½ 2½ 1½	In After Eng. Room
1	Do	Do	Do	Sea Drainage Hose Connection	3 3½ 1½	Fire Main Overboard Hose Connection	2½ 3½ 1½	In After Boiler Room
1	Aux. Circ for Aux. Condenser	9 diam Impeller	Electric Driven, Centrifugal	Sea	5	Aux. Condenser	5	In Ford. Eng. Room
1	Aux Air	6x10x8	Vertical, Piston, Double-Acting, Single, "Warren"	Aux. Condenser	4½	Feed Tank	4	Do
1	Evaporator Feed	4½x6x6	Do	Sea Distiller Circ. Disch.	2 1½	Evaporators	1½	In After Eng. Room
1	Distiller Fresh Water	Do	Do	Distiller Reservoir Tank	2½	Reserve Feed Tanks Ship's Tanks Cofferdam Main Feed Tank	2 2 2 1½	Do
1	Oil Cooler Circ	7x7x12	Do	Sea	3	Oil Cooler Fire Main via Oil Cooler	2½	Do
2	Lubricating Oil	6x7x8	Do	Lub Oil Tank	3½	Bearings Settling Tanks via Forced Lub. System	3 1½	Do
4	Fuel-Oil Service	5½x3½x8	Do	Oil Storage Tanks Booster-Pump Disch	2½ 2½	Burners	2	2 in each Boiler Comp't
2	Fuel-Oil Booster	4½x6x6	Do	Storage Tanks Deck-Hose Connection	3 3	Service-Pump Supply Storage Tanks Deck-Hose Connection	2½ 2½ 2½	One in each Boiler Room

leave through perforated plates in the bottom of the chamber after passing through the filtering material.

Auxiliary Condenser.—An auxiliary condenser, connected through the auxiliary exhaust pipe to all auxiliary machinery, is located in the forward engine-room. It is of the curved-tube type with tubes rolled in both tube sheets. The following principal dimensions are given:

Diameter of shell, maximum, inside, inches	22⅝
Thickness of shell, inch	0 3/16
Tubes, number	334
diameter, inch	0⅝
thickness, inch	0.049
Mean distance between tube sheets, feet and inches	5–8
Cooling surface, square feet	310
Diameter auxiliary exhaust nozzle, inches	8
air-pump suction, inches	4½
circulating water inlet and outlet, inches	5

Feed-Water Heater.—There is a feed-water heater of the direct-flow type installed in the forward engine room, on the discharge side of both the main and auxiliary feed pumps. The heating agent is the exhaust steam, a back pressure being kept in the auxiliary exhaust line for this purpose by means of a spring-relief valve at each condenser connection, opening toward the condenser. The principal dimensions of the heater are as follows:

Diameter of shell, inside, inches	23½
Thickness of shell, inch	$0\frac{3}{16}$
Length between tube sheets, feet and inches	6–0
Tubes, number	509
diameter, inch	$0\frac{5}{8}$
thickness, inch	0.049
Heating surface, square feet	500
Diameter of feed inlet and outlet, inches	6
auxiliary exhaust nozzle, inches	8
drain, inches	2

Forced-Lubrication System.—The main bearings, thrust bearings, reduction gears and circulating-pump engine are provided with forced lubrication.

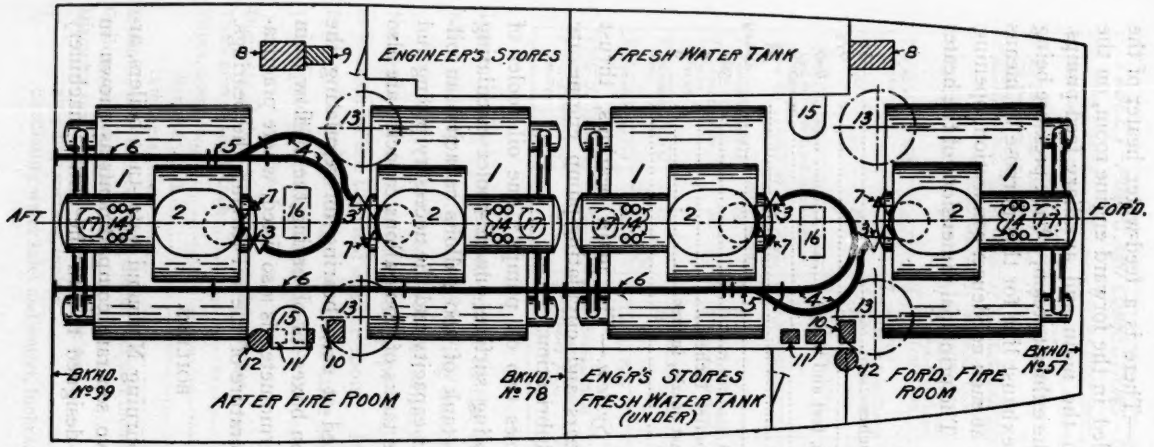
The system comprises two oil pumps,* one oil cooler of 291 square feet of cooling surface, one oil-cooler circulating pump,* one oil drain tank of 200 gallons capacity, an oil-settling tank of similar capacity and the necessary piping and fittings. Main storage tanks of 600 gallons capacity are also provided.

Lock cocks are fitted at each bearing for regulating the supply, and observation boxes for observing the oil flow from each bearing. A thermometer is also fitted, where practicable, to show the temperature of the oil leaving the bearings.

BOILERS.

There are four oil-burning Normand water-tube boilers, arranged in pairs in two separate compartments as shown in Plate III. They are designed to run the entire machinery

*See Table I.



ITEM	DESCRIPTION	ITEM	DESCRIPTION
1	BOILER	10	FUEL OIL BOOSTER PUMP
2	SMOKE PIPE	11	" " SERVICE "
3	7" MAIN STEAM STOP VALVE	12	" " HEATER
4	7½" O.D. MAIN STEAM PIPE	13	TURBINE DRIVEN BLOWER
5	MAIN STEAM EXPANSION JOINT	14	4" DUPLEX SAFETY VALVES
6	10¾" O.D. MAIN STEAM PIPE	15	AIR LOCK
7	3" AUX. STEAM STOP VALVE	16	FIRE ROOM HATCH
8	AUX. FEED PUMP	17	ESCAPE HATCH
9	FIRE AND BILGE PUMP		

PLATE III - U.S.S. WADSWORTH - ARRANGEMENT OF FIRE ROOMS.

plant at full power, with an average air pressure in the fire-rooms of about five inches of water.

Each boiler has an independent smoke pipe 20 feet high above the main deck.

Data for one Boiler.

Working pressure, pounds	260
Number of furnaces	1
Furnace volume, cubic feet	520
Area through smoke pipe, square feet	19.2
Smoke pipe area / Furnace volume	0.0368
Heating surface, square feet	5,375
Heating surface / Furnace volume	10.34
Oil burners, number	12
type	Modified Bureau of S. E.
External height, feet and inches	14–11 7/8
width, feet and inches	16–02 1/8
length, feet and inches	13–09 1/2
Tubes, outside diameter, inches	1 1/2–01 1/2
thickness, inch	0.12–0.109
number	116–1,594
Downcomers, inside diameter, inches	10
thickness, inch	0 1/2
number	2
Drum, upper, number	1
inside diameter, inches	44
thickness, shell, inch	0 1 1/16
tube sheet, inches	1 3/16
lower, number	2
inside diameter, inches	19
thickness, shell, inch	0 7/16
tube sheet, inch	0 1/2
Diameter of main steam stop valve, inches	7
auxiliary steam stop valve, inches	3
safety valves (two duplex Ashton), inches	4
main and auxiliary feed, stop and check valves, ins.	3
bottom-blow valves, inches	1 1/4
surface-blow valves, inches	1 1/4

FUEL-OIL SYSTEM.

The fuel-oil pumps and heaters are located in the firerooms as shown in Plate III.

The plant consists of two light-service booster pumps,*

* See Table I.

four heavy-pressure service pumps,* two oil heaters, and the oil-storage tanks in the forward and after holds, together with the necessary piping and fittings.

The booster pumps have suctions from all storage tanks and the deck connection for taking on oil, and discharge to all storage tanks, service pumps' suctions and the deck connections.

The service pumps draw oil from the storage tanks and the booster pumps' discharges, and deliver it to the oil burners on the boilers, via the oil heaters or bypasses. The burners, twelve per boiler, of the slightly modified Bureau of Steam Engineering type, are mechanical atomizers.

A small hand oil pump is installed in each fireroom for supplying oil to the burners when raising steam.

FIREROOM AUXILIARIES.

Forced-Draft Blowers.—Four forced-draft blowers are installed, two in each fireroom. The fans are of the Keith single-inlet type, mounted on vertical shafts in the base of the fireroom ventilators, from which the air supply is taken Each fan is driven by a 24-inch vertical Terry steam turbine located immediately below the fan.

The fan data is as follows:

Fan, diameter mean, inches	41⅝
width over all, inches	13 7/16
number of blades	24
Diameter of inlet, inches	35
R.P.M. (designed)	1,600

Pumps.—Table I contains the list of fireroom pumps and connections.

MAIN STEAM PIPING.

The main steam piping is of seamless-drawn steel, with composition valves and fittings. The arrangement is clearly shown in Plates I and III, hence, further description is unnecessary.

*See Table I.

AUXILIARY STEAM PIPING.

There is a 3-inch stop valve on each boiler for supplying the auxiliary steam line, which leads throughout the machinery spaces with connections to the various auxiliaries and a branch forward to the deck machinery, forward heating system and galleys. It is of same material as the main steam piping.

AUXILIARY EXHAUST PIPING.

An auxiliary exhaust pipe, of copper, extends throughout the machinery spaces and elsewhere as required for the various auxiliaries. Connections are provided for direct exhaust into either the main or the auxiliary condensers, the feed-water heater, or into the atmosphere through the after escape pipe, at will. There are also connections for admitting exhaust steam into the L.P. turbine's steam belt and into the fifth and eighth expansions of the H.P. turbine when desired.

MAIN AND AUXILIARY FEED PIPING.

The main and auxiliary feed pumps take their suctions from the feed suction main, which extends from the bottom of the main feed tank to the auxiliary feed pump in the forward fireroom. The main is 8 inches in diameter in the engine room, decreasing in size to 7 inches in the after fireroom and 5½ inches in the forward fireroom. The suction branches to all feed pumps are 5½ inches in diameter. All feed pumps are arranged to feed any boiler via the feed heater or bypasses. The main feed line is 6 inches in diameter from the feed-water heater to first branch connection to boilers, decreasing in size to 5 to 4 inches, as it leads forward in the firerooms. The discharge from each pump is 4 inches and the branches to all boilers are 3 inches each. Each auxiliary feed pump also has a direct connection to all boilers, through a 4-inch independent main between the two firerooms.

INTERIOR COMMUNICATION.

The customary engine-room and fireroom telegraphs, gongs, telephones, voice tubes, etc., are fitted for transmitting orders

and signaling to the machinery compartments and other parts of the vessel.

EVAPORATING AND DISTILLING APPARATUS.

The distilling apparatus is installed in the after engine room.

There are two evaporators and two distillers, with their accessories, arranged to operate in single or double effect. The plant has a combined nominal capacity of 5,400 gallons of water per twenty-four hours, with overload capacity 40 per cent. in excess of the nominal capacity when plant is clean.

Data for one Evaporator.

Type	Vertical, U-tubes.
Capacity per 24 hours, gallons	2,700
Diameter, inside, inches	34
Thickness of shell, inch	$0\frac{3}{16}$
Height overall, feet and inches	6–8
Tubes, number	50
diameter, inches	$1\frac{1}{4}$
thickness, inch	0.095
Heating surface, square feet	110
Diameter of steam nozzle, inches	2
vapor nozzle, inches	$3\frac{1}{2}$
feed valve, inch	1
blow valve, inches	2

Data for one Distiller.

Type	Vertical, straight tube.
Capacity per 24 hours, gallons	2,700
Diameter, outside, inches	$10\frac{1}{2}$
Thickness of shell (copper), inch	0.109
Length between tube sheets, inches	$30\frac{1}{8}$
Tubes, number	109
diameter, inch	$0\frac{5}{8}$
thickness, inch	0.049
Cooling surface, square feet	45.14
Diameter of circulating-water inlet and outlet, inches	2
vapor inlet, inches	2
drain, inches	$1\frac{1}{4}$

MACHINE TOOLS.

For performing minor repairs one small motor-driven engine lathe, of 12 inches swing and 6-foot bed, is installed in the

after engine room, together with all the necessary tools and attachments. The driving motor is a 1¼-horsepower, direct-current, Reliance, adjustable-speed type, with speed ranges from 500 to 1,500 r.p.m.

ELECTRIC PLANT.

The dynamos are located in the forward engine room. The installation consists of two horizontal, compound-wound, direct-current, 25-kilowatt, General Electric generators, each driven by a Curtis steam turbine. Each generator will deliver at normal load 200 ampères of current at 125 volts, when running 3,600 revolutions per minute.

TORSION METERS.

Each line of shafting is fitted with a Gary-Cummings torsionmeter for ascertaining the shaft horsepower of the main turbines.

TRIALS.

The contract required the following trials for each vessel:

(*a*) A progressive trial over a measured-mile course at Rockland, Me., for standardizing the screws, extending from maximum speed (at least 30 knots) down to a speed of 8 knots.

(*b*) A full-speed trial of four hours' duration in the open sea in deep water, at the highest speed attainable, the average for the four hours not to be less than 30 knots.

Four fuel-oil and water-consumption trials, designated (*c*), (*d*), (*e*) and (*f*), of four hours' duration in the open sea in deep water, at an average uniform speed of 25, 20, 16 and 12 knots, respectively, as nearly as possible. The trials to be conducted as nearly as possible to service conditions.

(*g*) Trials to determine the ability of the vessel to back satisfactorily at full speed and at cruising speed, and one trial to determine the time required to bring the vessel dead in the water, and the distance head reached, when steaming ahead at 30 knots.

Fuel-Oil Consumption Guarantee.—The contractors guar-

anteed that the consumption of fuel oil per knot run, for all purposes, including that necessary for all auxiliaries in use on trial, shall not exceed 641 pounds at 30 knots, 403 pounds at 25 knots, 245 pounds at 20 knots, 233 pounds at 16 knots and 203 pounds at 12 knots, the consumption of fuel oil at these speeds to be determined by a curve based on the rate of fuel oil consumed on trials (*b*), (*c*), (*d*), (*e*) and (*f*), and corrected to a standard of 19,500 B.t.u. per pound of fuel oil.

The trials were conducted June 21 to 24, 1915, inclusive. The contract speed was exceeded without effort, and the fuel-oil consumption guarantees were improved upon beyond expectation. Twenty-six runs were made on the standardization trial (*a*), as noted in Table II, which gives the data used in plotting the curves, Plate IV.

TABLE II — U.S.S. WADSWORTH
STANDARDIZATION TRIAL DATA — JUNE 21, 1915

No. of Run	Time on Course		Speed in Knots	R.P.M.			S.H.P.		
	Mins.	Secs.		Star. Engine	Port Engine	Mean	Star. Engine	Port Engine	Total
1	7	15.8	8.26	101.32	101.66	101.49	73	72	151
2	8	12.0	7.32	102.35	102.61	102.48	79	87	166
3	6	59.5	8.58	104.30	102.71	103.51	81	65	146
Mean of Group			7.87			102.49			157
4	5	23.1	11.07	151.08	151.05	151.07	277	245	522
5	4	44.3	12.66	156.34	154.82	155.58	331	240	571
6	5	23.5	11.13	150.15	149.98	150.07	244	233	477
Mean of Group			11.88			153.08			535
7	3	35.4	16.71	211.97	211.34	211.76	638	702	1360
8	3	49.8	15.67	210.29	210.02	210.16	727	682	1409
9	3	35.8	16.68	211.06	211.09	211.08	670	700	1370
Mean of Group			16.18			210.79			1387
10	2	57.8	20.25	272.54	272.62	272.58	1520	1578	3098
11	2	52.0	20.93	271.15	271.80	271.48	1493	1592	3085
12	2	56.3	20.42	272.97	272.99	272.98	1503	1638	3141
Mean of Group			20.63			272.13			3102
13	2	27.1	24.47	337.23	337.33	337.38	3237	3335	6572
14	2	29.3	24.11	337.39	337.27	337.33	3203	3285	6488
15	2	26.9	24.51	337.67	337.72	337.70	3170	3289	6459
Mean of Group			24.30			337.44			6502
16	2	13.7	26.33	388.09	387.37	387.83	5187	5343	10530
17	2	11.2	27.44	389.46	389.62	389.54	5195	5388	10583
18	2	13.2	27.03	388.00	388.36	388.18	5121	5425	10546
Mean of Group			27.21			388.52			10561
19	1	58.4	30.41	449.14	449.02	449.08	7608	7764	15372
20	2	00.0	30.00	447.52	446.22	447.87	7330	7812	15142
21	1	57.9	30.53	450.12	451.24	450.68	7657	7739	15396
Mean of Group			30.24			448.88			15263
22	1	53.3	31.17	485.22	485.35	485.29	8904	9113	18017
23	1	52.4	32.03	486.30	486.17	486.24	8408	9232	17640
24	1	55.6	31.14	484.90	484.43	484.67	9310	9059	18369
25	1	51.6	32.26	486.81	486.89	486.85	8660	9114	17782
26	1	55.7	31.11	487.29	487.33	487.31	9254	9186	18440
Mean of Group			31.64			486.02			18005

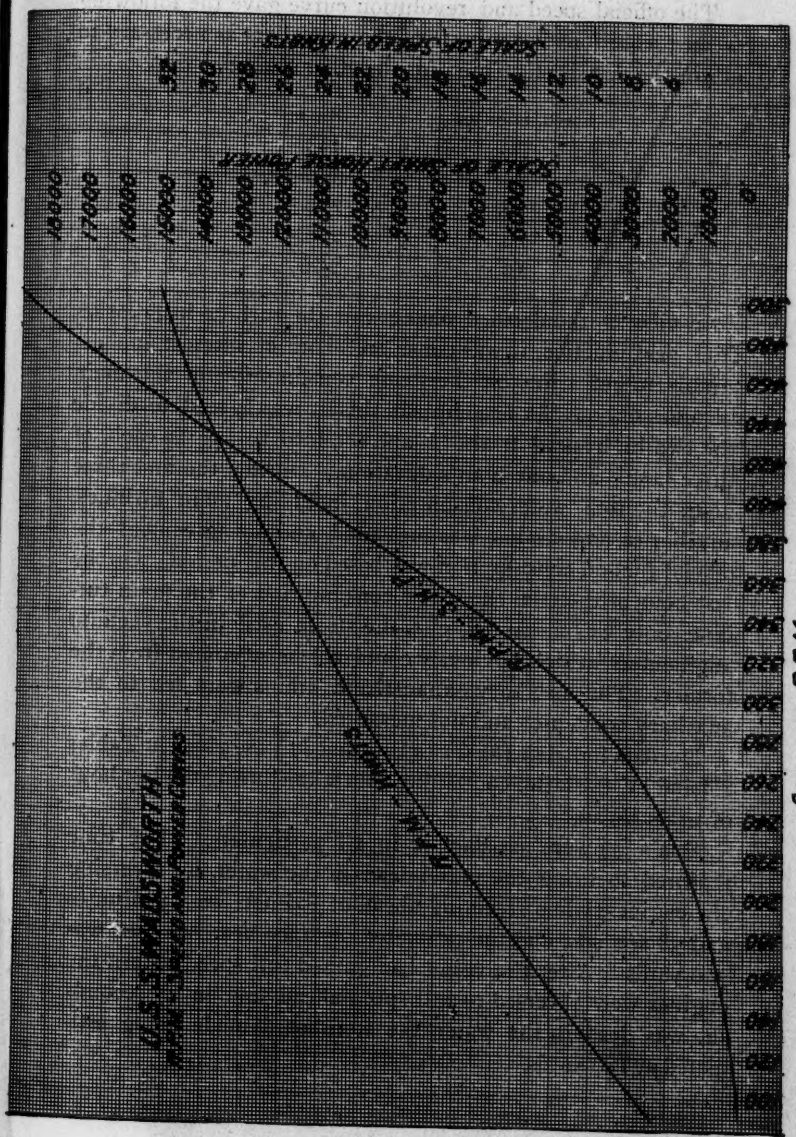


PLATE IV.

The official speed and revolution curve gave the following mean revolutions per minute of the propellers as necessary to attain the speeds stipulated for the other trials:

Speed, in knots.	R.p.m
30, ...	443.2
25, ...	349.8
20, ...	262.5
16, ...	208.5
12, ...	154.7

In view of the decided changes in the turbine installation from past practice, it was considered both of interest and desirable to get a line on the steam consumption of the main turbines only. To accomplish this it was agreed to divide the two high-speed trials, (*b*) and (*c*), into two parts each, of three hours' and one hour's duration. During the first three hours the total water consumption, including main turbines, auxiliaries and drains, was measured, and by agreement the official fuel-oil consumption was based on this period. On the last hour of the trial the water consumption of the main turbines only was measured, plus the steam used in the vacuum augmenters, which obviously could not be separated from the former. The auxiliary exhaust and drains were led to the auxiliary condenser and not measured.

The data for trials (*b*), (*c*), (*d*), (*e*) and (*f*) are given in Tables III and IV, the latter containing data taken during the last hour of trials (*b*) and (*c*).

Trials (*g*) were satisfactory in all particulars. The time required to bring the vessel dead in the water, by reversing the engines, when steaming ahead at 30 knots, was 3 minutes and 38 seconds, and the estimated distance head reached was 500 yards. After the vessel had gained full speed astern the engines were reversed to full speed ahead, and in 47 seconds she was dead in the water, the sternboard made being estimated at 150 yards.

TABLE III – TRIAL DATA – U.S.S. WADSWORTH

	4-Hrs. Full Speed Trial (b)	4-Hrs. 25 Kt. Trial (c)	4-Hrs. 20 Kt. Trial (d)	4-Hrs. 16 Kt. Trial (e)	4 Hrs. 12 Kt. Trial (f)
Date of Trial	June 22, 1915.	June 22, 1915	June 23, 1915.	June 23, 1915	June 24, 1915.
Speed in Knots	30.685	24.99	20.086	16.004	11.991
Draught, Mean on Trial, Feet and Inches	9-1	9-1⅝	9-2½	9-1½	9-1½
Displacement, Corresponding, Tons	1034.2	1042	1049	1043.7	1044.6
Slip of Propellers, Percent, Starb'd.-Port	21.76 | 21.28	16.04 | 15.92	10.62 | 10.34	9.86 | 9.67	8.95 | 8.73
Mean	21.52	15.98	10.48	9.77	8.84
Number of Boilers used	4	4	2	1	1
Burners used (12 per boiler)	36.375	16	8	5.25	2.625
Heating Surface used, Sq. Ft.	21500	21500	10750	5375	5375
Sq. Ft. per S.H.P.	1.335	2.887	3.669	3.743	3.755
Cooling Surface, Sq. Ft. (main cond.) per S.H.P.	0.671	1.451	3.689	7.527	19.617
Pressures (Average):	S. Eng. | P. Eng.	S. Eng. | P. Eng.	S. Eng. | P. Eng.	S. Eng. | P. Eng.	S. Eng. | P. Eng.
Main Steam at Boilers, Pounds Gauge	250.1	248.22	202	150	151.25
Eng. Room, " "	240.88 | 240.06	242.13 | 242.0	194.75 | 194.25	140.0 | 140.25	141.25 | 140.0
H.P. Ahead Chest, Pounds Absolute	225.38 | 245.06	205.63 | 215.0	89.38 | 107.75	54.5 | 64.88	34.0 | 37.5
Main Belt, " "	184.94 | 205.69	73.25 | 88.13	32.75 | 41.0	17.5 | 20.25	15.0 | 15.0
6th Expansion, " "	85.31 | 95.63	32.5 | 39.0	13.63 | 15.0	8.75 | 9.56	6.13 | 5.38
L.P. Chest, " "	23.78 | 27.3	9.5 | 13.5	5.3 | 6.0	4.5 | 4.5	2.39 | 2.91
Vacuum, Main Cond., Inches of Mercury	28.46 | 28.38	29.26 | 28.98	29.26 | 29.05	28.9 | 28.03	28.46 | 28.65
Aux. Cond. " "	LAST HR. 21.6	LAST HR. 18.0	NOT USED	NOT USED	NOT USED
Barometer, Inches of Mercury	29.53	29.12	29.46	29.46	29.55
Aux. Steam, Pounds Gauge	241.6	243.75	194.5	141.12	140.63
Exhaust, " "	10.76	5.13	4.57	9.56	5.1
Gland Steam, " "	0.88 | 0.25	0.30 | 0.19	0.19 | 0.25	0.49 | 0.25	0.41 | 0.25
Main Feed, at Pumps, Pounds Gauge	345.0	327.82	353.13	250.0	240.0
Forced Lubrication, " "	36.94	33.63	30.06	33.25	28.5
Oil at Main Thrust, " "	6.38 | 7.91	5.8 | 7.11	5.55 | 7.8	6.46 | 8.76	7.01 | 8.15
Reduction Gear, (H.P. Pinion), Pds. Gauge	6.87 | 4.05	6.44 | 3.49	6.43 | 4.2	7.11 | 4.94	7.01 | 4.88
(L.P. Pinion), " "	7.01 | 5.68	6.44 | 4.81	6.06 | 4.91	6.89 | 5.98	6.9 | 5.55
Fuel Oil, Pounds Gauge	116.4	103.76	84.0	99.38	107.5
Air Pressure in Fire Rooms, Inches of Water	6.02	3.14	2.5	2.55	2.5
Revolutions or Double Strokes per Min. (Average):					
Main Shafts, Starb'd.-Port	458.85 | 460.44	349.5 | 349.72	263.57 | 263.82	208.44 | 208.44	154.61 | 154.56
Mean	459.65	349.61	263.7	208.44	154.59
Main Air Pumps	19.81 | 18.94	14.38 | 16.88	(1) 27.0	(1) 21.75	(1) 21.63
Aux. Cond. Air Pump	LAST HR. 61.8	LAST HR. 43.0	NOT USED	NOT USED	NOT USED
Circulating Pump	ONLY 1134	ONLY 1121.66	DO.	DO.	DO.
Main Feed Pumps	(2) 24.82	(2) 14.07	(1) 14.0	(1) 8.76	(1) 9.0
Forced Lub. Pumps	(2) 59.6	(1) 75.0	(1) 52.13	(1) 43.5	(1) 32.38
Forced Draft Blowers	(4) 1335	(4) 886.25	(2) 774.38	(2) 812.82	(2) 778.76
Fuel Oil Service Pumps	(3) 23.82	(2) 17.52	(1) 19.13	(1) 15.88	(1) 9.5
Shaft Horse Power (Average):					
Starb'd. Shaft	8066	3729	1534	797	292
Port "	8034	3719	1395	639	259
Total	16100	7448	2930	1436	551
Temperatures, Degrees F. (Average):					
Main Air Pump Discharge	69.19	63.37	59.88	62.88	69.88
Feed Tank	71.38	64.13	61.13	64.13	65.63
Injection	54.81	54.57	52.38	52.67	52.07
Outboard Delivery	67.5 | 68.25	60.75 | 60.88	56.5 | 56.25	56.25 | 55.5	53.63 | 53.13
Outside Air	61.75	61.13	62	61.63	59.75
Engine Room	88.25 | 67.38	79.88 | 66.0	78.75 | 60.38	81.5 | 69.13	76.26 | 71.75
Fire Rooms	95.75	92.63	85.38	93.0	84.88
Feed Water	186.25	199.75	213.5	230.25	218.75
Oil Drains, H.P. Turbines, For'd. Bearings	125.81 | 119.06	115.38 | 106.13	103.5 | 98.38	98.0 | 91.88	93.38 | 87.13
After "					

OUTSIDE AIR	61.75		61.13		62		61.63		59.75
ENGINE ROOM	88.25	67.38	78.88	66.0	78.75	60.38	81.5	69.13	76.25	71.75
FIRE ROOMS	95.75		92.63		95.38		93.0		84.88	
FEED WATER	186.25		199.75		213.5		230.25		218.75	
OIL DRAINS, H.P. TURBINES, FOR'D. BEARINGS	125.81	119.06	115.38	106.13	103.5	98.38	98.0	91.88	93.38	87.13
AFTER "	124.69	116.25	110.5	102.63	105.75	94.88	96.5	90.13	90.0	83.38
L.P. TURBINES, FOR'D. "	112.63	112.19	99.75	99.38	90.25	92.63	89.25	87.0	84.38	81.63
AFTER "	112.19	114.38	99.0	103.5	91.75	94.88	88.63	90.0	82.75	83.88
MAIN THRUST	110.31	107.25	96.38	91.38	87.5	84.88	83.63	82.29	74.25	74.38
REDUCTION GEAR PINION BEARINGS, H.P.	112.75	112.44	98.75	111.0	89.75	98.75	84.25	92.13	80.0	85.0
L.P.	114.56	118.38	100.75	104.63	91.25	93.88	86.25	89.25	80.03	83.13
FUEL OIL TO HEATERS	69.03		70.94		70.25		72.38		71.63	
BURNERS	151.35		153.82		164.13		162.25		162.5	
SMOKE PIPES	664.69		465.31		408.58		442.5		443.75	
WATER CONSUMPTION:	FIRST 3 HRS.		FIRST 3 HRS.							
POUNDS PER HOUR, MEASURED	199467		92547.67		44985.25		30449.25		19793.75	
RESERVE FEED	2207		2263		291.5		NONE		NONE	
TOTAL EVAPORATED	201674		94810.67		45276.75		30449.25		19793.75	
PER S.H.P.	12.533[§]		12.725[†]		13.453		21.204		35.923	
EVAP'D PER SQ. FT. OF H.S.	9.38		4.41		4.212		3.665		3.603	
LB. OF OIL	13.126[•]		13.85[•]		14.533[•]		14.694[•]		14.167[•]	
KNOT RUN	6574.968[▲]		3785.919[▫]		2254.145		1902.602		1650.717	
FUEL OIL CONSUMPTION:										
B.T.U. PER POUND	19658.5		19658.5		19658.5		19658.5		19658.5	
SP. GR. AT 60°F.	0.8726		0.8726		0.8726		0.8726		0.8726	
POUNDS PER HOUR*	13364.09[•]		6845.41[•]		3115.4[•]		2072.16[•]		1397.21[•]	
KNOT RUN	500.9[•▲]		274.07[▫]		155.1[•]		129.48[•]		116.82[•]	
AT	30 Kts. 473[•]		25 Kts. 275[•]		20 Kts. 153.5[•]		16 Kts. 129.48[•]		12 Kts. 116.52[•]	
GUARANTEED AT	641[•]		403[•]		245[•]		283[•]		203[•]	
BELOW GUARANTEE	168[•]		128[•]		91.5[•]		103.52[•]		86.48[•]	
HOUR PER S.H.P.	0.855[•§]		0.919[•†]		1.063[•]		1.443[•]		2.536[•]	
SQ. FT. OF H.S.	0.715[•]		0.318[•]		0.28[•]		0.386[•]		0.26[•]	
SPECIAL DATA TAKEN IN FOR'D. ENGINE ROOM: (ALL READINGS INCHES OF MERCURY, ABSOLUTE)										
L.P. TURBINE EXHAUST	2.18		1.33		1.14		1.29		1.55	
AHEAD DUMMY	2.13		1.4		1.04		1.18		1.63	
ASTERN "	2.11		1.39		1.04		1.16		1.61	
MAIN CONDENSER, TOP	1.71		1.3		1.04		1.15		1.63	
BOTTOM	1.49		1.26		1.05		1.15		1.64	
AIR PUMP SUCTION	2.19		2.28		2.14		2.3		3.46	

NOTES.- FIGURES IN BRACKETS ( ) INDICATE NUMBER OF AUXILIARIES IN OPERATION. * THE POUNDS PER HOUR, AT 19658.5 B.T.U. PER POUND OF OIL, FOR THE VARIOUS TRIALS WERE; (b) FIRST 3 HOURS, 15240.19; (c) FIRST 3 HOURS, 6790.21 (d) 3090.28; (e) 2055.45; AND (f) 1385.84. • ON BASIS OF 19500 B.T.U. PER POUND OF OIL. § ON BASIS OF 16091 S.H.P., AVERAGE FOR FIRST 3 HOURS. † ON BASIS OF 7452 S.H.P., AVERAGE FOR FIRST 3 HOURS. ▲ ON BASIS OF 30.673 KNOTS, AVERAGE FOR FIRST 3 HOURS. ▫ ON BASIS OF 24.977 KNOTS, AVERAGE FOR FIRST 3 HOURS.

TABLE IV - SUPPLEMENTARY TRIAL DATA - U.S.S. WADSWORTH

	LAST HOUR OF	
	4-HOUR FULL SPEED TRIAL	4-HOUR 25-KNOT TRIAL
SHAFT HORSE POWER	16129	7435
SPEED IN KNOTS	30.72	25.03
OIL BURNED, POUNDS	1544[illegible]	6658.55
Do.	[illegible]	[illegible]

DISPLACEMENT, CORRESPONDING, TONS			1034.2		1042		1049		1043.7		1044.8	
SLIP OF PROPELLERS, PERCENT, STARB'D.-PORT			21.76	21.28	16.04	15.92	10.62	10.34	9.86	9.67	8.95	8.73
MEAN			21.52		15.98		10.48		9.77		8.84	
NUMBER OF BOILERS USED			4		4		2		1		1	
BURNERS USED (12 PER BOILER)			36.375		16		8		5.25		2.625	
HEATING SURFACE USED, SQ. FT.			21500		21500		10750		5375		5375	
SQ. FT. PER S.H.P.			1.335		2.887		3.669		3.743		3.755	
COOLING SURFACE, SQ. FT. (MAIN COND.) PER S.H.P.			0.671		1.451		3.689		7.527		19.617	
PRESSURES (AVERAGE):	S. ENG.	P. ENG.	S. ENG.	P. ENG.	S. ENG.	P. ENG.	S. ENG.	P. ENG.	S. ENG.	P. ENG.
MAIN STEAM AT BOILERS, POUNDS GAUGE			250.1		248.22		202		150		151.25	
ENG. ROOM, " "	240.88	240.06	242.13	242.0	194.75	194.25	140.0	140.25	141.25	140.0
H.P. AHEAD CHEST, POUNDS ABSOLUTE	225.38	245.06	205.63	215.0	89.38	107.75	54.5	64.88	34.0	37.5
MAIN BELT, " "	184.94	205.69	73.25	88.13	32.75	41.0	17.5	20.25	15.0	15.0
8TH EXPANSION, " "	85.31	95.63	32.5	39.0	13.63	15.0	8.75	9.56	6.13	5.38
L.P. CHEST, " "	23.73	27.3	9.5	13.5	5.3	6.0	4.5	4.5	2.39	2.91
VACUUM, MAIN COND., INCHES OF MERCURY	28.48	28.34	29.26	28.98	29.26	29.05	28.3	28.03	28.46	28.65
AUX. COND., " "	LAST HR. 21.6		LAST HR. 18.0		NOT USED		NOT USED		NOT USED	
BAROMETER, INCHES OF MERCURY			29.53		29.12		29.46		29.46		29.55	
AUX. STEAM, POUNDS GAUGE			241.6		243.75		194.5		141.12		140.63	
EXHAUST, " "			10.76		5.13		4.57		2.56		5.1	
GLAND STEAM, " "	0.88	0.25	0.30	0.19	0.19	0.25	0.49	0.25	0.41	0.25
MAIN FEED, AT PUMPS, POUNDS GAUGE			345.0		327.82		353.13		250.0		240.0	
FORCED LUBRICATION, " "			36.94		33.63		30.06		33.25		26.5	
OIL AT MAIN THRUST, " "	6.38	7.91	5.8	7.11	5.55	7.8	6.46	8.76	7.01	8.15
REDUCTION GEAR, (H.P. PINION), PDS. GAUGE	6.87	4.05	6.44	3.49	6.43	4.2	7.11	4.94	7.01	4.88
(L.P. PINION), " "	7.01	5.68	6.44	4.81	6.06	4.91	6.89	5.98	6.9	5.55
FUEL OIL, POUNDS GAUGE			116.4		103.76		84.0		99.38		107.5	
AIR PRESSURE IN FIREROOMS, INCHES OF WATER			6.02		3.14		2.5		2.55		2.3	
REVOLUTIONS OR DOUBLE STROKES PER MIN. (AVERAGE):												
MAIN SHAFTS, STARB'D.-PORT	458.85	460.44	349.5	349.72	263.57	263.82	208.44	208.44	154.61	154.56
MEAN	459.65		349.61		263.7		208.44		154.59	
MAIN AIR PUMPS	19.81	18.94	14.38	16.88	(1) 27.0		(1) 21.75		(1) 21.63	
AUX. COND. AIR PUMP	LAST HR. 61.8		LAST HR. 43.0		NOT USED		NOT USED		NOT USED	
CIRCULATING PUMP	ONLY 1134		ONLY 1121.66		DO.		DO.		DO.	
MAIN FEED PUMPS	(2) 24.82		(2) 14.07		(1) 14.0		(1) 8.76		(1) 9.0	
FORCED LUB. PUMPS	(2) 59.6		(1) 75.0		(1) 52.13		(1) 43.5		(1) 32.38	
FORCED DRAFT BLOWERS	(4) 1335		(4) 886.25		(2) 774.38		(2) 812.82		(2) 778.76	
FUEL OIL SERVICE PUMPS	(3) 23.82		(2) 17.52		(1) 19.13		(1) 15.88		(1) 9.5	
SHAFT HORSE POWER (AVERAGE):										
STARB'D. SHAFT	8066		3729		1534		797		292	
PORT "	8034		3719		1395		639		259	
TOTAL	16100		7448		2930		1436		551	
TEMPERATURES, DEGREES F. (AVERAGE):										
MAIN AIR PUMP DISCHARGE	69.19		63.37		59.88		62.88		69.88	
FEED TANK	71.38		64.13		61.13		64.13		65.63	
INJECTION	54.81		54.57		52.38		52.57		52.07	
OUTBOARD DELIVERY	67.5	68.25	60.75	60.88	56.5	56.25	56.25	55.5	53.63	53.13
OUTSIDE AIR	61.75		61.13		62		61.63		59.75	
ENGINE ROOM	88.25	67.38	78.88	66.0	78.75	60.38	81.5	69.13	76.25	71.75
FIRE ROOMS	95.75		92.63		85.38		93.0		84.88	
FEED WATER	186.25		199.75		213.5		230.25		218.75	
OIL DRAINS, H.P. TURBINES, FOR'D. BEARINGS	125.81	119.06	115.38	106.13	103.5	98.38	98.0	91.88	93.38	87.13
AFTER "	126.69	116.25	110.5	102.63	105.75	94.88	96.5	90.13	90.0	83.38
L.P. TURBINES, FOR'D. "	112.63	112.19	99.75	99.38	90.25	92.63	89.25	87.0	84.38	81.63
AFTER "	112.19	114.38	99.0	103.5	91.75	94.88	88.63	90.0	82.75	83.88
MAIN THRUST	110.31	107.25	96.38	91.38	87.5	84.88	83.63	82.29	74.25	74.38
REDUCTION GEAR PINION BEARINGS, H.P.	112.75	112.44	98.75	111.0	89.75	98.75	84.25	92.13	80.0	85.0
L.P.	114.56	118.38	100.75	104.63	91.25	93.88	86.25	89.25	80.03	83.13
FUEL OIL TO HEATERS	69.03		70.94		70.25		72.38		71.63	
BURNERS	151.38		153.82		164.13		162.25		162.5	
SMOKE PIPES	664.69		465.31		408.58		442.5		443.75	
WATER CONSUMPTION:	FIRST 3 HRS.		FIRST 3 HRS.							
POUNDS PER HOUR, MEASURED	199467		32547.67		44985.25		30449.25		19793.75	

L.P.	114.56 / 110.38	100.75 / 104.63	91.25 / 93.88	86.25 / 89.25	80.03 / 83.13
FUEL OIL TO HEATERS	69.03	70.94	70.25	72.38	71.63
BURNERS	151.35	153.82	164.13	162.25	162.5
SMOKE PIPES	664.69	465.81	408.58	442.5	443.75
WATER CONSUMPTION:	FIRST 3 HRS.	FIRST 3 HRS.			
POUNDS PER HOUR, MEASURED	199467	92547.67	44985.25	30448.25	19793.75
RESERVE FEED	2207	2263	291.5	NONE	NONE
TOTAL EVAPORATED	201674	94810.67	45276.75	30449.25	19793.75
PER S.H.P.	12.533§	12.723†	15.453	21.204	35.923
EVAP'D PER SQ.FT. OF H.S.	3.38	4.41	4.212	3.665	3.683
LB. OF OIL	13.126°	13.85°	14.533°	14.694°	14.167°
KNOT RUN	6574.968▲	3785.313°	2254.145	1902.602	1650.717
FUEL OIL CONSUMPTION:					
B.T.U. PER POUND	19658.5	19658.5	19658.5	19658.5	19658.5
SP. GR. AT 60°F.	0.8726	0.8726	0.8726	0.8726	0.8726
POUNDS PER HOUR*	13364.05°	6845.41°	3115.4°	2072.16°	1397.21°
KNOT RUN	500.9°▲	274.07°	155.1°	129.48°	116.52°
AT	30 Kts. 473°	25 Kts. 275°	20 Kts. 153.5°	16 Kts. 129.48°	12 Kts. 116.52°
GUARANTEED AT	641°	403°	245°	233°	203°
BELOW GUARANTEE	168°	128°	91.5°	103.52°	86.48°
HOUR PER S.H.P.	0.855°§	0.919°†	1.069°	1.443°	2.526°
SQ. FT. OF H.S.	0.715°	0.318°	0.29°	0.386°	0.26°
SPECIAL DATA TAKEN IN FOR'D. ENGINE ROOM: (ALL READINGS INCHES OF MERCURY, ABSOLUTE)					
L.P. TURBINE EXHAUST	2.18	1.33	1.14	1.29	1.55
AHEAD DUMMY	2.13	1.4	1.04	1.18	1.63
ASTERN "	2.11	1.39	1.04	1.16	1.61
MAIN CONDENSER, TOP	1.71	1.3	1.04	1.15	1.63
BOTTOM	1.49	1.26	1.05	1.15	1.64
AIR PUMP SUCTION	2.19	2.28	2.14	2.3	3.46

NOTES.- FIGURES IN BRACKETS ( ) INDICATE NUMBER OF AUXILIARIES IN OPERATION. * THE POUNDS PER HOUR, AT 19658.5 B.T.U. PER POUND OF OIL, FOR THE VARIOUS TRIALS WERE; (b) FIRST 3 HOURS, 15240.19; (c) FIRST 3 HOURS, 6790.21 (d) 3090.28; (e) 2055.45; AND (f) 1385.94. ° ON BASIS OF 19500 B.T.U. PER POUND OF OIL. § ON BASIS OF 16091 S.H.P., AVERAGE FOR FIRST 3 HOURS. † ON BASIS OF 7452 S.H.P., AVERAGE FOR FIRST 3 HOURS. ▲ ON BASIS OF 30.673 KNOTS, AVERAGE FOR FIRST 3 HOURS. ° ON BASIS OF 24.977 KNOTS, AVERAGE FOR FIRST 3 HOURS.

TABLE IV - SUPPLEMENTARY TRIAL DATA - U.S.S. WADSWORTH

	LAST HOUR OF 4-HOUR FULL SPEED TRIAL	LAST HOUR OF 4-HOUR 25-KNOT TRIAL
SHAFT HORSE POWER	16129	7435
SPEED IN KNOTS	30.72	25.03
OIL BURNED, POUNDS	15446.68	6658.55
DO.	*15572.23	*6712.68
OIL PER KNOT RUN, POUNDS	* 506.94	* 268.19
WATER PER HOUR, TOTAL CONSUMPTION FROM FIRST 3 HOURS OF TRIAL, POUNDS	199467	92548
MAIN TURBINES AND AUGMENTER ONLY, POUNDS	180468	78537
AUXILIARIES AND LOSSES, POUNDS	°18999	°14011
MAIN TURBINES AND AUGMENTER ONLY PER S.H.P., POUNDS	11.19	10.56

* ON BASIS OF 19500 B.T.U. PER POUND OF OIL.
° DIFFERENCE BETWEEN TOTAL CONSUMPTION, FIRST 3 HOURS AND CONSUMPTION MAIN TURBINES AND AUGMENTER, LAST HOUR.

LAND STORAGE OF BITUMINOUS COAL; THE EVER PRESENT FACTOR OF SPONTANEOUS COMBUSTION; AND A FEW FACTS AND SUGGESTIONS IN CONNECTION WITH SAME.

By Geo. R. Crapo, Paymaster, U. S. N., Naval Station, Key West, Fla.

Preface.—If the publishing of this article will result in the Departments of the Government making a careful investigation of every fire that occurs in coal-storage plants under their cognizance, and a record kept of same embracing the following: type of shed in which combustion took place, kind of coal, daily rise of temperature from time of taking in to time of combustion, length of time before combustion took place, whether coal was wet or dry when taken in, whether coal was green (freshly mined) or old, and the proportion of lump and dust in same, it is believed that valuable data will be collected, sufficient to save not only the Government but the commercial world large sums of money annually, and furthermore arrive at a condition whereby the Government will be able to store more coal in its present plants without fear of combustion.

The writing of this article is occasioned by the fact that from November 15th, 1914, to February 20th, 1915, a series of fires of a spontaneous nature, sixteen in all, took place in the coaling plant under my charge at the Naval Station, Key West, Fla.

The amount of worry, night calls and work, accompanied by a considerable expense in the continual handling of this hot coal for the purpose of cooling same, made it imperative that some study be given this matter that a re-occurrence might not occur. Not only from a standpoint of economy should this matter be made a subject of rigid investigation, but more vitally from a logistical standpoint, and for the following reason, which probably applies to other stations as well.

The plant at this station consists of two steel sheds: one 150 feet × 100 feet × 20 feet at the eaves, the other 250 feet

× 75 feet × 20 feet at the eaves. From the above dimensions, using 42.5 as the average density of coal, it is readily seen that the plant was built for the purpose of storing 15,883 tons of coal within ready reach of the conveyors for rapidity of handling. The best authorities now contend that coal cannot be safely stored at a depth of over 14 feet, and even at that depth a careful watch has to be kept on same.

This means that a plant designed to store coal in such manner that rapid discharge and loading of vessels can be effected, and with a capacity of nearly 16,000 tons, can only be utilized for the storage of approximately 11,000 tons.

If this condition applies to other naval storage plants (and I believe it does to a great extent) a large amount of government funds have been expended unnecessarily, as well as valuable property utilized for an unnecessary purpose, and, furthermore, an even more vital item presents itself in view of the fact that these plants being built for a certain capacity would probably be called upon in time of war to work to this capacity, and conditions might very probably arise that when this coal was very urgently needed, it would either be too hot to place in the vessels' bunkers with safety, or that the prolonged and continual process of heating had so exhausted its calorific qualities as to render it not good steaming coal. If not this, even the fact that the plant was not worked to capacity might seriously affect the situation by the lack of the amount of coal, the difference between what could be carried with reasonable safety and the plant's designed capacity.

Does it not appear that something is radically wrong; either our system of storage, or our lack of information on the subject, which if available might enable one to overcome existing conditions with the present plants?

One thing is certain that very little is known, or, if known, it has never been published; and, furthermore, it is believed that only a small percentage of coal combustions in land storage plants have ever been reported and made a subject of thorough investigation.

The existing published data on this subject is not complete, very inaccessible, and often contradictory. To quote Edgar Stansfield, M. Sc., McGill University, in his article on spontaneous combustion of coal, "A study of extensive literature bearing upon spontaneous combustion has shown that although much has been accomplished, a great deal more remains to be done. This literature is not easily accessible, and although there have been excellent summaries published, these chiefly refer to the question of shipment of coal cargoes, so that there does seem a need for a statement as to the known facts and present theories with especial reference to land storage."

In order that there will be no misunderstanding as to what takes place prior to ignition of coal, I wish to quote from the as yet unpublished notes of Mr. F. R. Wadleigh, Consulting Engineer, on this subject. "Spontaneous combustion of coal is a gradual cumulative absorption of oxygen, slow at first, but gradually gathering in amount with increasing temperature of the coal, until the ignition point is reached and the coal fires."

CONDITIONS UNDER WHICH COAL IS MORE LIABLE TO FIRE, AND SUPPOSED CONTRIBUTING CAUSES WHEREBY COAL IS EXCITED TO POINT OF IGNITION.

(*a*) If the surface of coal exposed is large.

(*b*) If air is supplied only at a rate sufficient to supply the required oxygen.

(*c*) If the heat generated cannot rapidly escape.

(*d*) When green coal (freshly mined) is stored with old coal.

(*e*) When coal both very fine (dust) and lump are stored together in a heap of any great height.

In addition to the above, Prof. Fischer, of Göttingen, has given to the world a very simple but practical method of determining in advance whether or not a coal in question can be safely stored, namely: "Coals which absorb bromine rapidly

are most liable to spontaneous ignition, and recommends the shaking of one grain of finely ground coal with 20 c.c. of a half normal solution of bromine for a period of five minutes. If the smell of the bromine has then disappeared, the coal is liable to oxidize rapidly and is not a safe one to store." Prof. Lewes also gives some further information as follows: "Coal that gains more than 2 per cent. in weight when heated to 250 degrees F. for 3 hours, is a very dangerous coal to store."

The above tests, being simple and requiring no elaborate or expensive apparatus, could be readily incorporated in the inspection and analysis of coals prior to loading, and forwarded in advance to the person to whom the coal is consigned, thus giving that person valuable information, whereby every precaution can be taken in coals that show by these tests an unusual tendency to develop heat.

SUPPOSED CAUSES.

(*a*) Escape of combustible gases when fresh surfaces are exposed.

(*b*) Absorption of oxygen from the air with consequent evolution of heat.

(*c*) Presence of moisture in abnormal percentages.

(*d*) External heat.

(*e*) Oxidation of sulphur compounds.

(*f*) Oxidation of bituminous shales.

(*g*) Climatic conditions.

(*h*) Depth to which coal is stored.

(*i*) Lack of proper ventilation.

The above ascribed causes are taken from the works of Perry Barker, Edgar Stansfield, McGill University, Messrs. Parr and Kressman, University of Illinois, and also from personal experience and observation.

Relative to the above-mentioned conditions under which coals fire most favorably, condition "A" is borne out both in theory and practice, as, regardless of technical expressions and phrases in which various authorities ascribe the reasons for

spontaneous combustion of coal, it resolves itself in plain English to "Absorption of oxygen," consequently the greater surface exposed the greater and more rapid the process of absorption.

Condition "B."—It being the air that supplies the oxygen, it stands to reason, and experience bears it out, that with air supplied only at a rate sufficient to furnish the required amount of oxygen for this process of absorption, the air currents, or ventilation, are insufficient to carry off the heat. In other words, I believe that insufficient ventilation is worse than none at all.

The remarks as to condition "B" are applicable to condition "C."

Condition "D."—Why this is I do not know, but time and time again in discharging a collier it has been necessary to place coal from this same collier both in empty bins as well as filling partially empty bins containing old coal, and invariably the mixture of old and new coal heats much more rapidly than the coal placed by itself, and, furthermore, I have seen the mixed bin fire where the solid bin remained almost as cool as when taken out of the vessel.

Condition "E."—Coal dust has now become accepted as not only an explosible agent but a carrier of the flames after ignition has taken place.

Reference is invited to page 13, Bureau of Mines Bulletin No. 20. "Mr. Henry Hall, English Mines Inspector,—experiments at St. Helens in an adit or drift—coal dust was laid on the floor and shots were fired at the face of the adit and the flames traveled its length of about 135 feet."

With a mixture of lump and dust the lumps create pockets, veins, run ways, etc., and each time a plant is placed in operation the continual trampling and shoveling of the stevedores excite the dust already deposited, as well as creating more dust, which arises temporarily and then settles back, filling all these interstices, and when coal has become heated to a point of ignition near one of these trains of dust, it is possible for

the flames to be carried rapidly to the end of the train, which might be some point quite distant, and the heat deposited in a favorable place for the starting of another fire. Furthermore, this fine dust clogs up all avenues of escape of generated heat and interferes with ventilation which might otherwise prevent this pile from heating to a danger point.

Relative to contributing causes, it has been stated elsewhere in this article that the existing data on this subject is often contradictory.

Causes "A" and "B."—These causes are agreed upon unanimously by the various authorities, and I have found nothing in experience and practice that offers proof to the contrary.

"C" Presence of Moisture in Abnormal Percentages.—It has been a generally accepted theory that excessive moisture in coal in land storage plants was a large factor in the process of heating. Quoting the Bureau of Supplies and Accounts in its letter 504–10a of March 4th, "Moisture, sulphur in the form of pyrites, etc., are considered to have a contributory effect toward spontaneous combustion."

Mr. Perry Barker, in his article on spontaneous combustion of coal, also ascribes this cause as an important factor; but, turning to the report of the Royal Commission appointed by the New South Wales Government, 1898, for the express purpose of settling this question of moisture, we find: "The experiment was made by placing 245½ tons of small coal in each of two similar bins, placed side by side under a roof, so that surface ventilation was secured. The sides of the bins were made of boards and no attempt was made to stop up the cracks between the boards, so that air could penetrate the coal with sufficient freedom.

"The coal in the two bins was of the same character, each wagon of coal being divided between the two bins. In one case the coal was loaded in an air-dry condition; in the other the coal was thoroughly wetted by playing a hose on it while it was being shoveled into the bin, and it was so saturated with moisture that the water ran out of the bottom of the bin. Each

bin was fitted with several thermometer tubes for ascertaining the temperature.

"The coal was bituminous and its analysis showed 14 per cent. ash, 0.5 per cent. sulphur. Daily observations of the temperatures were taken on a regular system.

"Results: The temperature of the dry coal rose steadily from 122 degrees F., its mean temperature after loading, till after about 60 days it reached 392 degrees F. in its central part, and was on the point of catching fire, when the experiment was stopped in order to avoid conflagration.

"In the wet coal the temperature of the central part only increased from 106 degrees F. to 138 degrees F. in 38 days, after which the temperature decreased.

"The inference is that wet coal is far less liable to spontaneously heating than dry coal."

I have handled coal both wet and dry; have discharged vessels in a downpour of rain, and while fires have at times broken out in both wet coal and dry coal, less trouble has been experienced with wet coal.

"D." As to whether or not this has a bearing on the question of spontaneous combustion I cannot say, as the plant at this station is situated where no external heat can be applied other than the heat of the sun, which I do not believe has any material effect, as most of the fires at this station have been in the coolest months; and, furthermore, while the fires referred to at the beginning of this article were constantly occurring, fire of a spontaneous nature also broke out at the plant at the Navy Yard, Boston.

"E." I have not noticed that this has any material effect, and am borne out in my opinion by Mr. F. R. Wadleigh, in his as yet unpublished notes on spontaneous combustion, as follows: "The long-held theory that sulphur or iron pyrites was the main or at least a largely contributing cause, has been pretty well proved to be incorrect and misleading."

"F." In connection with this cause I can only state that in the piles and near the seat of the fire, shale and the "motheri"

have been noticed in varying quantities when digging the fire out.

"G." Having only studied conditions as they exist at Key West, an almost tropical climate, I am unable to state, but the Government having coaling plants in all latitudes can by comparison probably arrive at this conclusion.

"H" and "I." It is believed that these two have a direct relation inasmuch as the height to which coal can be stored is dependent upon the completeness of the ventilation. In other words, I contend that coal can be stored in the open at a greater height than in the inclosed shed and be a safe coal to handle.

A concrete instance that seems to bear out this contention is that during the several winter months that the Michigan Northern Peninsular is closed to navigation large quantities of coal are stored for the purpose of operating the many mines in that section. This coal is stored in the open (with merely a roof to prevent the coal from being buried under a deep fall of snow) and piled much higher than would possibly be attempted in a shed, and yet it is very rare indeed where one reads of a spontaneous combustion in these piles.

RECOMMENDATIONS AND SUGGESTIONS BASED UPON THE FOREGOING FACTS AND CONDITIONS.

It is believed that an open shed with just enough superstructure to support the overhead mechanical devices for rapidity of handling of coal is far superior and safer than the closed type. It is possible that a light roof that can be easily opened and shut might be an advantage. It is especially so at this station where we are so dependent upon rain for our water supply, as these roofs are great collection agencies for water.

In this connection I wish to state that facts (local) do not bear out the statement of Commodore W. H. Beehler appearing some time ago in the "Naval Institute," "It is claimed that if a ton of fine bituminous coal be spread out on a concrete pavement and exposed in open air in this climate for one

year, it will lose all its calorific properties. The gases are simply free to evaporate from the coal, and when the coal has lost all its gases it will have lost all its heat units and be simply coke."

There is a marked difference physically between coal and coke, and it is doubted very much if the simple exposure to the elements will make this transformation without the aid of extreme heat.

The Florida East Coast Railway, The Peninsular and Occidental Steamship Company, and the Mallory Steamship Company, as well as several commercial concerns, keep varying quantities of coal at Key West in the open, much of it that I have seen having been stored here considerably over one year without any change in appearance, and this coal is still being used for steaming purposes with good results. Probably some of the calorific properties have been lost, but not any great amount, unless this coal has been subjected, as before said, to extreme heat; in fact, to approximately the ignition point.

Regarding the mechanical appliances for handling coal, many plants use the overhead-conveyor system, the apron being from 45 to 60 feet above the floor of the shed. In many, many instances I have seen buckets containing from two to five tons dumped from that height to a concrete (or other) hard surface used as flooring.

This is a dangerous procedure for two reasons: 1st, The coal in its fall generates some additional heat, and before this heat can escape another bucketful is dropped upon the first, and so on, so that when your pile reaches 15 or 20 feet in height the original heat of the coal is augmented quite considerably. 2d, The fall from this height breaks a large percentage of the lump and creates more fine coal or dust, which in itself is a dangerous element.

In every instance reduce the amount of fall by lowering your bucket before tripping.

If one is obliged to use a closed shed, keep it as open as pos-

sible, and when storing coal have as many air passages as possible between and around the piles.

If possible when working the plant, devise some sprinkling device to prevent the rising and re-settling of fine dust.

Install tubes in all piles, through which thermometers can be lowered, and take daily readings of same, and if time will permit, take readings of temperature of coal in the various hatches of the collier prior to discharge. This reading makes a very fair basis on which to compare the subsequent heating.

Too much dependence, however, should not be placed in the temperature readings, as it very frequently happens that that portion of coal that fires first may not necessarily be the portion which indicated the highest thermometer reading, as it is possible, and often does happen, that the portion first heated may get a draft of air in consequence of the heating and the heat moved and deposited elsewhere. The accompanying photograph will illustrate an instance in the recent fires at this station. The pile, part of which is shown in the photograph, developed signs of heating to such an extent that the top of the pile was removed and the danger was thought overcome. This was late in the afternoon; the next morning, at some distance from the above referred to hot spot, and where the coal was only 8 inches in depth, as indicated in the photograph, fire was burning brightly like an open grate. I can only attribute this to one of two reasons: The hot portion getting a draft of air in consequence of its heating and removing the heat to this spot, or, a mixture of old and green coal with widely different analyses.

The large majority of fires at this station have come to a point of ignition where the coal is either in contact with a wall or around a stanchion and almost invariably where the coal was not deeply piled.

The promiscuous use of water in extinguishing fires in a coal pile is practically of no value and often misleading as to the results; furthermore, a coal pile will often heat almost to the point of coking and then subside, but if water is used at

this state the coking will take place at once and coal will be lost that otherwise could be saved.

The digging out of the heated portion is the only safe and sure way, and, if after segregation from the rest of the coal it is found that the coal is on fire, hollow out the top of the pile (like the crater of a volcano) and, after putting the water on the sides, fill the crater with water; the water seals up the pile and the gases being unable to escape bursts the pile open and the application of water can then be made and the fire extinguished in short order.

In addition to the thermometers above referred to, iron or steel rods run through the piles at various angles often reveal the extent of the most heated portion, and their constant use (probing) is recommended in addition to the thermometers.

Separation of lump from fine coal by screening is recommended whenever possible, using the fine coal first and reserving the lump.

The net loss by these sixteen fires was less than 10 tons of coal, and it is believed that strict adherence to the above *established* theories and practice was the reason for this very inconsiderable loss.

Inasmuch as the Government has large amounts of coal in storage under varying climatic and storage conditions, an excellent opportunity is presented whereby the world at large may be benefited, if every fire is reported and a personal rather than theoretical investigation made, going into all possible conditions and causes. These results, if properly recorded and filed, may in time lead to the solution of this problem, and the Navy Department be enabled to work their many plants to capacity without fear of disaster, and both the several branches of the Government and the commercial world relieved of this continual annual loss, together with the worry and work contingent upon same.

In conclusion, I wish to state that I consider this subject of sufficient importance to continue into its study, and for this

reason I would recommend to any reader interested in the foregoing remarks to read the following:

"The Iron and Coal Trades Review" of March 13, 1914.

"Deterioration and Spontaneous Combustion of Coal," by Perry Barker-Arthur D. Little, Inc., Chemists and Engineers, 93 Broad Street, Boston.

"Lloyds' Register of British and Foreign Shipping." Report by their chief engineer surveyor on spontaneous combustion of coal.

"Spontaneous Combustion of Coal," by Edgar Stansfield, M. Sc., McGill University, Montreal.

University of Illinois "Bulletin No. 46."

"The Spontaneous Combustion of Coal," by Messrs. S. W. Parr and F. W. Kressman.

Report to Messrs. Castner, Curran and Bullitt on fires at coal sheds, Key West, Fla., 1900–1901.

Bureau of Mines Bulletin No. 20, on "Coal Dust as an Explosive Agent."

I also wish to thank Mr. F. R. Wadleigh for many valuable suggestions, and also his aid in helping me to secure numerous articles on this subject that otherwise would have been unattainable.

NOTES.

IRON A FACTOR IN THE WORLD'S PROGRESS.*

By John Birkinbine, Consulting Engineer, Member of the Institute.

The European war, while drawing heavily upon the resources affecting industries of contending nations, also seriously influences conditions in countries throughout the world not engaged in hostilities, threatening lasting effect and possible future changes in many phases of development. For this reason a discussion is offered of the relative positions of the leading countries which produce pig iron or supply the requisite raw materials for its manufacture, and to indicate past as well as present conditions a period of at least four decades has been chosen as covering practically the era of greatest industrial growth.

Prognostications as to future conditions are not attempted, but analyses of the data presented may suggest possibilities for nations now prominent or others wherein the development or utilization of the above commodities is less pronounced, while similar studies of other industrial specialties may indicate even greater changes.

Iron ore and coal hold leading rank among mineral resources whose development has been and is coincident with the world's progress, for countries possessing these abundantly, or utilizing them liberally, are the dominant nations.

The United States produces more coal, more iron ore, and more pig iron than any other nation, and her strongest competitors are the European countries now at war, for they are each an important factor in the supply of some or all of the above, and, together with the United States, are depended upon for

85 per cent. of the iron ore,
96 per cent. of the pig-iron supply of the world,
89 per cent. of the coal.

They are also the most active producers of varied forms of iron and steel manufactures, a large proportion of their inhabitants being skilled and efficient in mine, furnace and mill work.

A disturbance as momentous as that produced by the European conflict is far-reaching in its effect upon industrial progress, and its influence may be expected to continue long after peace is declared; for animosities do not cease with the suspension of active hostilities.

Consideration of iron as a factor in the world's progress necessarily is dependent on statistics, but, to relieve the discussion of voluminous tables, charts are presented on which are traced the conditions prevailing since 1870 in iron ore, coal and pig-iron productions of important nations. The quantities recorded are in long tons (2,240 pounds), except for countries using the metric system, where the amounts are given in metric tons (2,204 pounds).

Iron Ore.—Plate A illustrates the annual production of iron ores in the countries which have been or are prominent in supplying this mineral. The ordinates indicate in tons (the space between two longitudinal lines

* Communicated by the Author.

representing five million tons) the outputs of each country, designated by a particular form of line; the abscissæ show the years. By tracing the "curve" for any country, its production in a given year is found, or its contemporaneous position with other iron-ore producing nations is demonstrated. Thus Plate A shows that Great Britain was the largest contributor of iron ore until 1889, when the United States took first place, and since 1895 Germany has exceeded the output of Great Britain. The contemporaneous contributions of the three nations were practically equal in the years 1893 and 1894, subsequent to which time the advance of Germany and of the United States has been more pronounced than that of

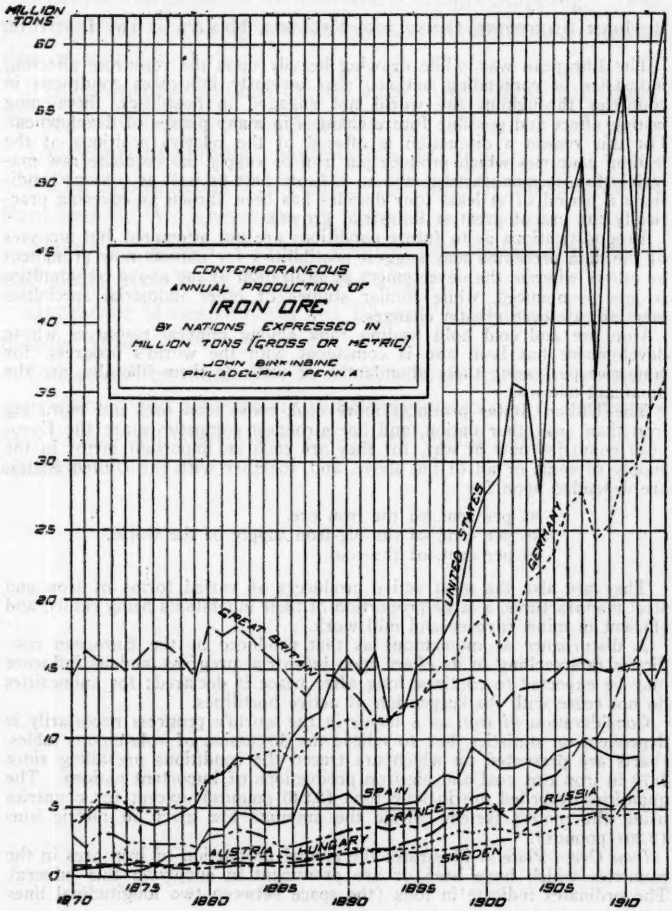


PLATE A.

Great Britain. In late years the iron-ore output of France has materially advanced. It will be noted that the maximum annual productions of iron ore, were for the United States 1913, Great Britain 1882, Germany and Luxemburg 1913,* France 1912, Spain 1907, Russia 1911 (?), Sweden 1913, Austria-Hungary 1911 (?).†

In addition to the countries designated in the graphic representation, the islands of Cuba and Newfoundland are each supplying about one and a half million tons of iron ore annually, and smaller amounts are mined in Canada, China, Greece, Italy, Algeria, Belgium, Tunis, Australia, India, Japan, Norway, Mexico, Brazil, Chile and Korea. Iron ore exists in minable quantities in most of the geographical divisions of the earth, and in some of these there are known reserves of enormous extent and of excellent quality.

The majority of iron ores obtained in Spain, Sweden, Russia and the United States average higher percentages of iron than those in Great Britain, Austria-Hungary, Germany and Luxemburg, France and Belgium. Hence the relative weights of iron ore obtained in the different countries may not be considered as equitably comparative, for two tons of ore containing 60 per cent. iron will produce as much metal as three tons of 40 per cent. ore. The world's output of iron ore approximates 157,000,000 tons, the United States furnishing 36 per cent., and the nations now actively engaged in hostilities in Europe supplying an aggregate of 49 per cent. of the total iron-ore product of the world. This resource is a most important factor, and it is asserted by some competent to judge that the control of the iron-ore deposits of what was then eastern France and Luxemburg had a potential influence in the Franco-Prussian war of 1870, and is a factor in the present conflict.

Pig Iron.—The graphic statement, Plate B, illustrates by ordinates, each space between horizontal lines representing 1,000,000 tons, the status of various countries as pig-iron producers subsequent to 1869, and indicates by "curves" the annual contribution of each nation in tons.

The diagram shows that England, which had long been preëminent in pig-iron manufacture, was outstripped by the United States in 1890, and that in 1903 Germany's product also exceeded that of Great Britain. Plate B, read in connection with Plate A, demonstrates that some important pig-iron producing countries depend to a greater or less extent upon other nations for iron ore, a feature which is later discussed.

Sweden, long celebrated for the excellence of its pig iron produced with charcoal as fuel, is included in Plate B, although its output is below, while those of all other nations shown on the diagram at present exceed 1,000,000 tons of pig iron annually. It will be noted that the maximum production of pig iron in each of the nations discussed was obtained within the past four years.

Among the countries supplying less than 1,000,000 tons of pig iron per year are: Canada (contributing over a half million tons), Spain, Italy, Japan, China, India and Mexico.

The production of pig iron indicates that various commercial forms of iron and steel into which it enters are also locally fabricated. The employment of liquid metal from blast furnaces for steel conversion, and of continuous processes of manipulation used in the manufacture of merchantable metal, causes the district which produces pig iron to attain prominence in supplying various forms of iron and steel, thereby advancing it as an important industrial factor.

To obtain pig iron, ores, fuels, fluxes and air are required; the last named is sufficiently abundant to cause no anxiety, and fluxes represent a minor part of the "charge." But the average ton of pig iron demands

* The statistics of Luxemburg, which supplies liberal quantities of iron ore and coal, have been officially combined with those of Germany.

† (?) intimates that no authentic records are available subsequent to the date mentioned.

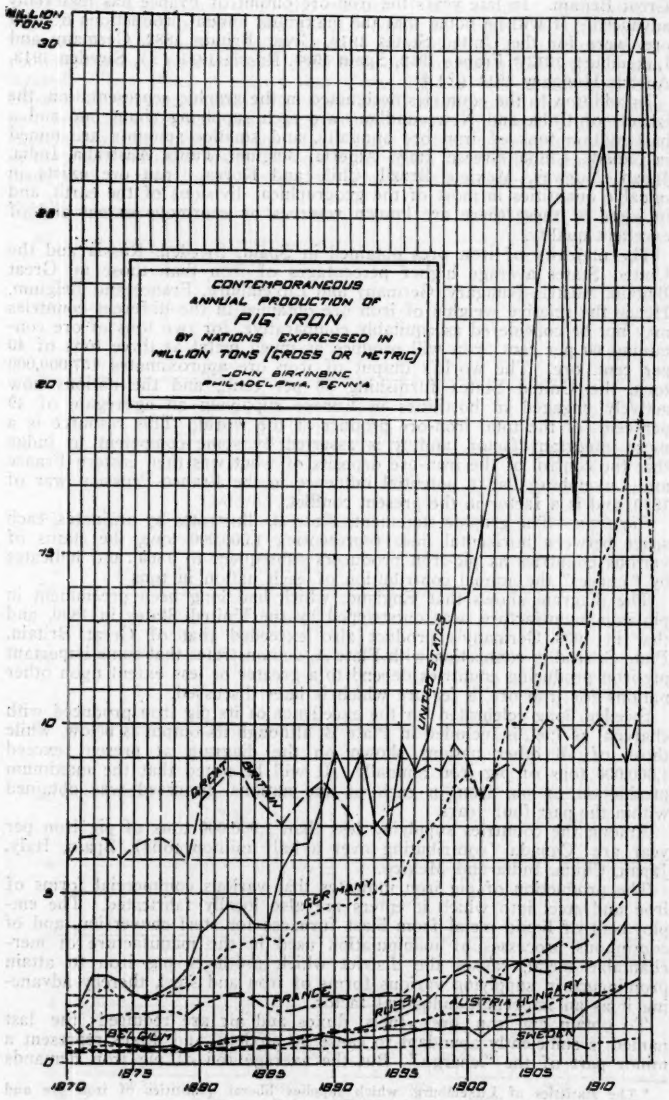

MILLION TONS
30
25
20
15
10
5
0
CONTEMPORANEOUS ANNUAL PRODUCTION OF PIG IRON BY NATIONS EXPRESSED IN MILLION TONS [GROSS OR METRIC]
JOHN BIRKINBINE PHILADELPHIA, PENN'A
UNITED STATES
GREAT BRITAIN
GERMANY
FRANCE
RUSSIA
AUSTRIA HUNGARY
BELGIUM
SWEDEN
1870
1875
1880
1885
1890
1895
1900
1905
1910

PLATE B.

for its production the consumption of two tons of ore and a ton or more of satisfactory fuel. Hence the nation having its own supply of iron ore, and ample metallurgical fuel of desirable quality, has an advantage in the race for industrial supremacy. The total quantity of pig iron produced throughout the world is in the neighborhood of 73,000,000 tons. This is exclusive of metal obtained from forges by crude methods in a number of countries. Upon the above basis the United States at present supplies 41 per cent., and the combined output of the European nations in conflict is 55 per cent. of the world's pig-iron product.

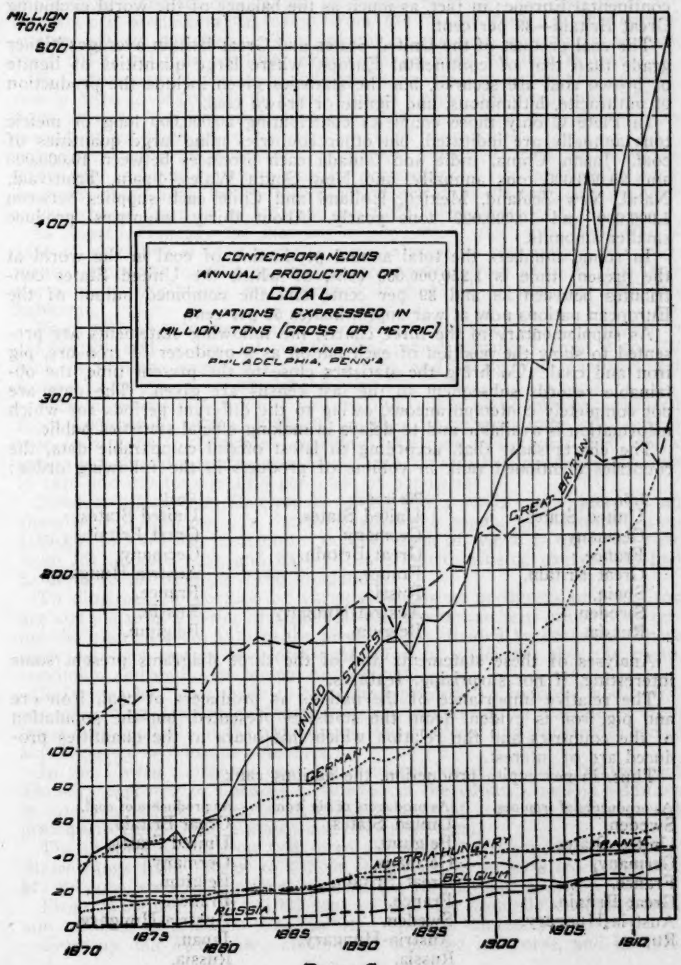


PLATE C.

Coal.—Plate C, which follows the form of Plates A and B, except that the spaces between horizontal lines represent 20,000,000 tons, illustrates the production of coal by various nations, and when read in connection with Plates A and B shows how different countries compare in the production and utilization of coal and iron ore.

England maintained preëminence in coal output until 1898, but since that date the United States has been in the lead, and in 1913 produced almost as much coal as its nearest competitors, Great Britain, Germany and Luxemburg, combined. The United States supplies more coal than all of continental Europe; in fact, as much as the balance of the world excluding Great Britain—39 per cent.

The coal product of the United States and Great Britain averages higher grade than that of continental Europe, where large quantities of lignite or brown coal are secured, but the statistics given include the production of anthracite, bituminous, and lignite or brown coal.

In Plate C only those countries contributing 20,000,000 long or metric tons annually are indicated, but other countries mine large quantities of coal. Japan, China, India and Canada each produces between 10,000,000 and 20,000,000 tons annually, and New South Wales, Spain, Transvaal, Natal, New Zealand, Mexico, Holland and Chile each supplies between 1,000,000 and 10,000,000 tons yearly. About thirty countries produce smaller amounts.

In round numbers the total annual production of coal in the world at the present time is 1,250,000,000 tons, of which the United States contributes between 38 and 39 per cent., and the combined output of the European nations now at war approximates 50 per cent.

As supplementary to the three charts, the following statements are presented to show the position of each nation as a producer of iron ore, pig iron and coal. To bring the statistics close to the present time, the obtainable records subsequent to the last census are given. The data are not completely contemporaneous, owing to the different periods for which information is available and to delays in making official statistics public.

The charts show that, according to latest official comparable data, the countries mentioned rank in volume of products in the following order:

Iron ore.	Pig iron.	Coal.
United States,	United States,	United States,
Germany,	Germany,	Great Britain,
France,	Great Britain,	Germany,
Great Britain,	France,	Austria-Hungary,
Spain,	Russia,	France,
Sweden,	Austria-Hungary,	Russia,
Russia.	Belgium.	Belgium.

Analyses of these statements and of the three diagrams present some interesting, if not surprising, features.

The relative importance of the nations as producers of coal, iron ore and pig iron is evident from the statistics presented, but the population of the countries and the relation which this bears to the quantities produced are of interest.

Thus, in per capita production, the nations rank:

As producers of iron ore.	As producers of pig iron.	As producers of coal.
Sweden,	United States,	Great Britain,
United States,	Belgium,	United States,
Germany,	Germany,	Germany,
France,	Great Britain,	Belgium,
Great Britain,	France,	France,
Austria-Hungary,	Sweden,	Austria-Hungary,
Russia.	Austria-Hungary,	Japan,
	Russia.	Russia.

Progress in iron ore and coal mining, and in the manufacture of pig iron, between the years 1870 and 1910, shows as follows for the various countries, the quantities being quoted as per 1,000 inhabitants:

In the interval of forty years the population of the United States increased from 38,500,000 to 92,000,000; its coal output rose from 765 to 4,869 tons; its iron ores mined from 100 to 620 tons, and its pig iron made from 43 to 297 tons per 1,000 inhabitants, the rate of increase being most pronounced in the last twenty years.

In the same period Great Britain's population advanced from 32,000,000 to 45,000,000, and its coal output increased from 3,685 to 5,994 tons, but its iron-ore production decreased from 513 to 342 tons (in the decade ending 1901 to 292 tons). The amount of pig iron manufactured rose from 208 to 214 tons per 1,000 inhabitants, reaching 231 tons in 1881.

In Germany and Luxemburg the population was augmented from 41,000,000 in 1871 to 66,000,000 in 1910; its coal output advanced from 922 to 3,360 tons, its iron ore production from 106 to 434 tons, and the pig iron manufactured from 38 to 224 tons per 1,000 inhabitants.

In forty years the population of France advanced from 36,000,000 to 39,600,000, and contemporaneously its proportionate coal production grew from 438 to 991 tons, its iron ore output from 85 to 404 tons, and pig iron manufactured from 34 to 113 tons per 1,000 inhabitants.

In Austria-Hungary the increase in population was from 36,000,000 in 1870 to 49,000,000 in 1910. In the same interval its coal output was augmented from 233 to 989 tons, its iron ore product from 32 to 92 tons, and the amount of pig iron manufactured from 13 to 41 tons per 1,000 inhabitants.

From 1870 to 1912 the population of Russia has risen from 85,000,000 to 171,000,000, and in that interval its coal mined advanced from 8 to 179 tons, its iron-ore output from 9 to 41 tons, and its pig iron manufactured from 4 to 24 tons per 1,000 inhabitants.

Belgium produces but little iron ore, but, while its population advanced from 5,000,000 in 1870 to 7,500,000 in 1910, its proportionate coal output rose from 2,692 to 3,222 tons, reaching 3,505 tons in the year 1900. This nation is a liberal manufacturer of pig iron, of which it produced 111 tons in 1870 and 249 tons in 1910 per 1,000 of population.

Sweden differs from Belgium in having but a small coal supply but an abundance of iron ore. In the forty years the population advanced from 4,000,000 to 5,500,000, its iron-ore output, much of which is exported, rose from 151 to 1,006 tons, and its pig-iron production using charcoal as fuel from 72 to 109 tons per 1,000 inhabitants.

To illustrate the position of various nations as producers of coal, iron ore and pig iron, a series of statistical statements has been prepared covering the interval from 1870 to the present time, divided by decades. These show for each nation the total production in a decade, also the mean, maximum and minimum annual productions.

Reference has been made to the interdependence of nations, and, without attempting detailed explanation, this is epitomized in statements from latest data available of the amounts of iron ore, coal and pig iron exported and imported by various countries.

In the *United States* all iron ore produced, except about 1,000,000 tons annually exported to Canada, is smelted in the country, and in addition, in late years, from 2,000,000 to 2,600,000 tons of iron ore are imported, principally from Cuba, Sweden and Newfoundland.

The imports of pig iron and ferro alloys in late years into the United States range from 130,000 to 237,000 tons, and the exports from 60,000 to 275,000 tons, showing that the domestic pig iron is used at home.

From 12,000,000 to 22,000,000 tons of coal are annually exported from and 1,250,000 to 2,000,000 tons imported into the United States.

Germany and Luxemburg smelt their domestic iron ores, and in addi-

tion import 11,000,000 to 14,000,000 tons, principally from Sweden, France and Spain, and have exported about 2,500,000 tons, chiefly to Belgium and to France.

Germany annually imports 125,000 to 140,000 tons, and exports in the neighborhood of 1,000,000 tons of pig iron.

Thirty-one million to thirty-four million five hundred thousand tons of German coal are exported to Austria-Hungary, Holland, Belgium, France, Sweden and Russia, and from 17,500,000 to 18,500,000 tons are imported into Germany.

Great Britain, in addition to its domestic iron-ore supply, draws 6,000,000 to nearly 8,000,000 tons from foreign mines, two-thirds coming from Spain, although Algeria, Norway, Sweden, Tunis, Greece and France contribute considerable quantities. No ore is exported.

Great Britain exports from 1,000,000 to 2,000,000 tons of pig iron, but the imports seldom exceed 250,000 tons.

Of its large fuel production, 65,000,000 tons of coal and about 1,000,000 tons of coke are exported to continental European, South American, and other countries. Those receiving more than 5,000,000 tons of British fuel annually are France, Italy, Germany, Sweden and Norway.

France.—Four million to over eight million tons of French iron ore are annually exported, principally to Belgium and Germany, and from 1,000,000 to 2,000,000 tons of iron ore are imported, mostly from Germany and Spain. France exported from 100,000 to 250,000 tons of pig iron annually, while its imports of this metal are less than half these amounts.

France imports (mostly from England) about 16,000,000 tons of coal and 2,000,000 to 2,750,000 tons of coke, while its fuel exports are from 1,300,000 to 2,000,000 tons.

Russia exports little iron ore, but about 4,000,000 tons of coal and 500,000 or more tons of coke are imported.

Austria-Hungary imports annually from 500,000 to 600,000 tons of iron ore, mainly from Sweden, and exports about 100,000 tons, principally to Germany. From 100,000 to 200,000 tons of pig iron are imported and 28,000 to 60,000 tons exported.

From 9,000,000 to 12,000,000 tons of coal are imported, principally from Germany, and 8,000,000 tons, mostly lignite, are exported, chiefly to Germany.

Spain is a large iron-ore producer, and exports 7,000,000 to 9,000,000 tons per year, the greater portion going to Great Britain. It produces 300,000 to 400,000 tons of pig iron, and its imports and exports are small. The domestic production of coal is augmented by importations of 2,000,000 tons annually.

Belgium mines from 125,000 to 250,000 tons of iron ore annually, but imports mostly from France, Germany and Spain 5,000,000 to 6,000,000 tons, about 500,000 tons of which are reëxported to Germany.

Belgium fabricates practically all of its pig-iron product, and also imports about two-thirds of a million tons annually, the larger part from Germany, although Great Britain and France also furnish pig iron. It mines from 22,000,000 to 24,000,000 tons of coal, imports 6,000,000 to 7,500,000 tons, and exports about 5,000,000 tons, principally to France.

Sweden produces an abundance of high-grade iron ore, the greater part of which is exported to Germany, England, Belgium and the United States. The pig-iron industry depends almost entirely on charcoal, about one-fourth of the production being exported.

The various nations have been discussed independently of any colonies or dependencies, for, as before stated, the pig iron made has not been followed through mills and factories. But the statements presented may indicate how intimate the association has been between nations now combating each other and seeking to cripple their adversaries in every possible manner. These may also suggest the present and prospective status of

each country as a contributor to the supply of resources necessary for the world's advancement, and show how changes of boundary lines may enlarge or reduce the independent manufacturing possibilities of the nations now at war.

On preceding pages reference has been made to the necessary interchange of the raw or the manufactured materials between the countries now at conflict, and it is possible that the result of the war may greatly strengthen some or seriously cripple others of the contestants, according to the peace terms which may be agreed upon. The commercial supremacy of each nation is, to a great extent, controlled by its ability to manufacture articles of iron and steel.

The effects of such changes may extend far beyond the limits of the countries contending with each other, and the possession of natural reserves of some nations or colonies and also in the Orient may be more than a mere incident in the European War.

PRODUCTION OF IRON ORE in the Eight Principal Iron-Ore Mining Countries in the World, from 1870 to 1913, by Ten-year Periods.

UNITED STATES—Long Tons.

Period.	Total production.	Mean annual production.	Year.	Maximum.	Year.	Minimum.
1870–79	44,645,440	4,464,544	1879	5,255,000	1876	3,734,000
1880–89	95,089,403	9,508,940	1889	14,518,041	1880	7,120,362
1890–99	163,989,193	16,398,919	1899	24,683,173	1893	11,587,629
1900–09	383,932,500	38,393,250	1907	51,720,619	1900	27,553,161
1910–13	218,022,042	54,505,510	1913	61,980,437	1911	43,876,552

GERMANY AND LUXEMBURG—Metric Tons.

1870–79	51,160,842	5,116,084	1873	6,177,576	1870	3,839,222
1880–89	89,499,306	8,949,931	1889	11,002,187	1880	7,238,640
1890–99	133,313,059	13,331,306	1899	17,989,635	1891	10,657,521
1900–09	224,434,495	22,443,450	1907	27,697,127	1901	16,570,182
1910–13	128,284,212	32,071,053	1913	35,941,285	1910	28,729,700

GREAT BRITAIN—Long Tons.

1870–79	156,173,886	15,617,389	1876	16,841,584	1870	14,370,655
1880–89	158,823,859	15,882,386	1882	18,031,957	1887	13,098,041
1890–99	130,184,239	13,018,424	1899	14,461,330	1893	11,203,476
1900–09	142,877,457	14,287,746	1907	15,731,604	1901	12,275,198
1910–13	60,533,158	15,133,290	1913	15,997,328	1912	13,790,391

FRANCE—Metric Tons.

1870–79	25,715,612	2,571,561	1872	3,081,026	1871	2,099,706
1880–89	28,743,748	2,874,375	1882	3,467,251	1886	2,285,648
1890–99	40,088,780	4,008,878	1899	4,985,702	1890	3,471,718
1900–09	76,317,045	7,631,705	1909	11,890,000	1902	5,003,782
1910–12	49,410,078	16,470,026	1912	18,800,000	1910	14,605,542

SPAIN—Metric Tons.

1870–79	9,419,302	941,930	1874	423,401	1877	1,576,150
1880–89	46,444,883	4,644,488	1887	6,796,266	1881	3,502,681
1890–99	63,292,106	6,329,211	1899	9,397,733	1892	5,041,317
1900–09	87,235,290	8,723,529	1907	9,896,178	1902	7,904,555
1910–11	17,440,486	8,720,243	1911	8,773,691	1910	8,666,795

RUSSIAN EMPIRE—Metric Tons.

Period.	Total production.	Mean annual production.	Year.	Maximum.	Year.	Minimum.
1870–79	9,166,008	916,601	1875	1,056,545	1871	794,779
1880–89	11,692,556	1,169,256	1889	1,646,840	1883	998,393
1890–99	30,468,011	3,046,801	1899	5,788,709	1890	1,802,165
1900–09	50,621,536	5,062,154	1900	6,122,270	1902	4,004,007
1910–11	12,750,218	6,375,109	1911	6,985,039	1910	5,765,179

SWEDEN—Metric Tons.

1870–79	7,466,982	746,698	1874	926,825	1870	630,739
1880–89	8,883,492	888,349	1889	985,904	1880	775,344
1890–99	17,402,164	1,740,216	1899	2,435,200	1890	941,241
1900–09	38,011,618	3,801,162	1908	4,713,160	1900	2,609,500
1910–13	25,886,414	6,471,604	1913	7,479,393	1910	5,552,678

AUSTRIA-HUNGARY—Metric Tons.

1871–79	10,246,331	1,138,481	1873	1,588,058	1877	884,260
1880–89	14,632,594	1,463,259	1889	1,780,772	1881	1,084,443
1890–99	25,162,976	2,516,298	1899	3,293,004	1892	1,913,831
1900–09	37,511,679	3,751,168	1908	4,568,814	1903	3,155,116
1910–11	9,245,998	4,622,999	1911	4,712,666	1910	4,533,332

PRODUCTION OF PIG IRON in the Eight Principal Pig-iron Producing Countries in the World, from 1870 to 1914, by Ten-year Periods.

UNITED STATES—Long Tons.

1870–79	21,885,266	2,188,527	1879	2,741,853	1870	1,665,179
1880–89	51,534,529	5,153,453	1889	7,603,642	1880	3,835,191
1890–99	93,538,215	9,353,822	1899	13,620,703	1894	6,657,388
1900–09	197,807,609	19,780,761	1909	25,795,471	1900	13,789,242
1910–14	134,978,776	26,995,755	1913	30,966,301	1914	23,332,244

GERMANY AND LUXEMBURG—Metric Tons.

1870–79	19,272,726	1,927,273	1873	2,240,575	1870	1,391,124
1880–89	36,195,906	3,619,591	1889	4,524,558	1880	2,729,038
1890–99	58,777,609	5,877,761	1899	8,143,132	1891	4,641,217
1900–09	105,500,005	10,550,001	1907	12,875,159	1901	7,880,087
1910–14	81,683,742	16,336,748	1913	19,309,172	1914	14,389,547

GREAT BRITAIN—Long Tons.

1870–79	63,796,993	6,379,699	1872	6,741,929	1870	5,963,515
1880–89	79,127,923	7,912,792	1882	8,586,680	1886	7,009,754
1890–99	79,614,624	7,961,462	1899	9,421,435	1892	6,709,255
1900–09	91,251,065	9,125,107	1906	10,149,388	1901	7,761,832
1910–13	39,306,601	9,826,650	1913	10,481,917	1912	8,889,124

FRANCE—Metric Tons.

1870–79	13,364,987	1,336,499	1878	1,521,274	1871	859,641
1880–89	17,723,834	1,772,383	1883	2,069,430	1886	1,516,574
1890–99	21,919,062	2,191,906	1899	2,567,388	1891	1,897,387
1900–09	30,278,382	3,027,838	1907	3,590,235	1901	2,388,823
1910–13	18,758,948	4,689,737	1913	5,311,316	1910	4,038,297

RUSSIA—Metric Tons.

Period.	Total production.	Mean annual production.	Year.	Maximum.	Year.	Minimum.
1870–79	3,805,983	380,598	1879	420,660	1871	339,513
1880–89	5,278,717	527,872	1889	733,720	1880	427,696
1890–99	15,113,846	1,511,385	1899	2,677,120	1890	905,460
1900–01	27,634,376	2,763,438	1904	2,962,283	1903	2,449,701
1910–12	10,830,846	3,610,282	1912	4,197,635	1910	3,040,047

AUSTRIA-HUNGARY—Metric Tons.

1870–79	4,423,447	442,345	1873	534,508	1877	387,630
1880–89	6,838,158	683,816	1889	855,822	1880	464,234
1890–99	11,431,258	1,143,126	1899	1,467,664	1891	921,846
1900–09	16,119,729	1,611,973	1909	1,995,511	1904	1,375,865
1910–12	6,545,212	2,181,737	1912	2,372,660	1910	2,060,975

BELGIUM—Metric Tons.

1870–79	5,379,203	537,920	1872	655,565	1879	389,330
1880–89	7,323,421	732,342	1889	832,226	1880	608,084
1890–99	8,631,404	863,140	1899	1,036,185	1891	684,126
1900–09	12,335,766	1,233,577	1909	1,616,370	1901	764,180
1910–13	8,726,830	2,181,708	1913	2,527,070	1910	1,852,090

SWEDEN—Metric Tons.

1870–79	3,343,027	334,303	1876	352,467	1871	298,761
1880–89	4,329,398	432,940	1885	464,737	1882	398,945
1890–99	4,873,948	487,395	1897	538,197	1893	453,421
1900–09	5,401,295	540,130	1907	615,778	1909	444,764
1910–13	2,668,404	667,101	1913	730,257	1910	603,939

PRODUCTION OF COAL in the Eight Principal Coal-Mining Countries in the World, from 1870 to 1913, by Ten-year Periods.

UNITED STATES—Long Tons.

1870–79	476,566,017	47,656,602	1879	60,808,749	1870	29,496,054
1880–89	1,019,753,264	101,975,326	1888	132,701,827	1880	63,822,830
1890–99	1,712,331,738	171,233,174	1899	226,554,635	1890	140,866,931
1900–09	3,337,185,589	333,718,559	1907	428,895,914	1900	240,789,310
1910–13	1,877,082,366	469,270,592	1913	508,971,540	1911	443,054,614

GREAT BRITAIN—Long Tons.

1870–79	1,274,494,850	127,449,485	1877	134,179,968	1870	110,431,192
1880–89	1,607,990,447	160,799,045	1889	176,916,724	1880	146,969,409
1890–99	1,910,785,455	191,078,546	1899	220,094,781	1893	164,325,795
1900–09	2,414,416,661	241,441,666	1907	267,830,962	1901	219,046,945
1910–13	1,084,171,738	271,042,935	1913	287,430,473	1912	260,416,338

GERMANY—Metric Tons.

1870–79	456,561,932	45,656,193	1879	53,470,716	1870	34,003,004
1880–89	719,117,229	71,911,723	1889	84,973,230	1880	59,118,035
1890–99	1,073,735,837	107,373,584	1899	135,824,427	1890	89,051,527
1900–09	1,791,128,249	179,112,825	1909	217,445,656	1900	149,788,256
1910–12	711,706,424	237,235,475	1912	255,810,094	1910	222,375,076

FRANCE—Metric Tons.

Period.	Total production.	Mean annual production.	Year.	Maximum.	Year.	Minimum.
1870–79	161,713,709	16,171,371	1873	17,479,341	1871	13,258,920
1880–89	208,703,065	20,870,307	1889	24,303,509	1881	19,361,564
1890–99	286,581,124	28,658,112	1899	32,863,000	1893	25,650,981
1900–09	346,903,640	34,690,364	1909	37,840,086	1902	29,997,470
1910–13	159,716,914	39,929,229	1912	41,145,178	1910	38,349,942

AUSTRIA-HUNGARY—Metric Tons.

1870–79	121,822,412	12,182,241	1879	14,891,024	1870	8,355,944
1880–89	202,430,110	20,243,011	1889	25,328,417	1880	16,128,718
1890–99	325,647,572	32,564,757	1899	38,739,000	1890	27,504,032
1900–09	439,719,257	43,971,926	1908	49,626,184	1900	39,502,301
1910–12	151,031,218	50,343,739	1912	52,521,776	1910	48,649,768

RUSSIA—Metric Tons.

1870–79	15,555,667	1,555,567	1879	2,874,790	1870	696,673
1880–89	43,237,790	4,323,779	1889	6,213,869	1880	3,286,534
1890–99	91,966,854	9,196,685	1899	14,311,200	1890	6,085,080
1900–09	204,227,251	20,422,725	1909	26,075,086	1900	16,135,600
1910–12	83,551,747	27,850,582	1912	30,646,163	1910	24,898,345

BELGIUM—Metric Tons.

1870–79	146,893,125	14,689,313	1873	15,778,401	1877	13,669,077
1880–89	179,771,122	17,977,112	1889	19,869,980	1881	16,873,951
1890–99	206,800,233	20,680,023	1898	22,075,093	1893	19,410,519
1900–09	231,237,587	23,123,759	1907	23,705,190	1905	21,775,280
1910–12	69,942,240	23,314,060	1910	23,916,560	1912	22,972,140

JAPAN—Metric Tons.

1881–89	12,808,235	1,423,136	1889	2,388,614	1881	925,198
1890–99	45,721,857	4,572,186	1898	6,761,301	1890	2,608,284
1900–09	115,283,197	11,528,320	1909	14,973,617	1900	7,429,457
1910–12	52,953,789	17,651,263	1912	19,639,755	1910	15,681,324

—"Journal of the Franklin Institute."

TRIPLE AND QUADRUPLE SCREWS.

Twin, triple and quadruple screws are at present employed for the propulsion of large battleships. In the United States Navy there are several Dreadnaughts with twin screws driven by reciprocating machinery, whilst several large German and French warships are driven by three screws. The British practice is to have quadruple screws. Several considerations are taken into account when the number of screws are decided upon, such as the total power to be distributed. When this is not excessive either triple or quadruple may be adopted, and the question of the propulsive efficiency of these systems is then, amongst other things, taken into consideration. From experiments made in the Spezia tank it appears that higher efficiency may be looked for from a triple arrangement than from quadruple screws. Four screws have several disadvantages, amongst them being an increase in resistance due to the appendages of the shafts and a smaller utilization of the wake. In a triple-screw ship the center propeller is placed most advantageously for making use of the wake, whereas in quadruple screws the wing propellers are placed far out from the center line and are thus in a position of inferiority. It has also been shown by experiment that considerable interference is effected by the propeller race

from the forward pair of screws upon the wake of the after pair in a quadruple arrangement. In triple-screw warships driven by turbine machinery the distribution of power is equal and the three screws are generally of the same dimensions. In triple-screw merchant ships, fitted with the combination type of machinery, two large screws are placed on the wings and a small screw, driven by the turbine, is placed in the center position. It is most important from the point of view of propulsive efficiency that too much power should not be passed through the small center screw, as although the wake value is high, the propeller is generally too small to use the power efficiently. Although experiments indicate that triple screws are more efficient than quadruple, high propulsive efficiencies have been obtained with both arrangements, the triple-screw light cruisers being very efficient, as also were the quadruple-screw battle cruisers of the *Invincible* type.—"Shipbuilding and Shipping Record."

MODERN SUBMARINE TORPEDO BOATS OF THE UNITED STATES AND OTHER NAVIES.

By Herbert S. Howard, Naval Constructor, U. S. N.

Submarines in the present war have come so much to the front that not only navy men but the laymen throughout the country are evincing great interest in them. The questions which most frequently come to the front seem to be: How do they submerge? How deep do they go? How do they see? How fast can they go? How is it that German submarines can go away over into the Irish Sea or other waters about England and return to Germany? Do they carry guns as well as torpedo tubes? And very often: Are our submarines as good as the German submarines we read of?

In the first place, submarine boats must be strongly built, as they must withstand the pressure of water when they are submerged. For this reason the structure of submarines is heavy when compared to surface vessels, and must be made of a shape capable of resisting high pressure. It is the practice in all countries to design submarines to withstand submergence to depths of 150 to 200 feet, and beyond such depths they must not go.

To submerge a submarine boat water is admitted to ballast tanks, thus destroying the reserve buoyancy of the vessel. When it is desired to bring the vessel to the surface, water is pumped or blown by compressed air from these tanks. In some types of submarines these tanks are located within the main hull, which is circular in section. In some other types the tanks are located outside of the circular-section hull, between it and a light exterior hull, more or less ship-shaped. Our submarines and those of England are practically all of the first type, while those of Germany and France are of the latter type. In all submarines, however, water is taken in to submerge.

When submerged, submarines ordinarily receive no fresh air, and a submarine may remain submerged for about 10 hours before the air becomes too foul for breathing. In many foreign submarines devices for regenerating the air are fitted, to permit them to remain submerged a much longer time, and it is worth noting that devices of this nature have been tested and are now under consideration for the submarines of our Navy. When running submerged the submarine is supplied with one or more periscopes, with which it can see, provided the vessel is only a short distance below the surface. These are optical instruments with lens systems similar to those of a telescope, but with prisms at the top and bottom to turn the rays of light down, and out at the bottom. When completely

submerged, however, the submarine is blind. Various forms of searchlights, etc., have been suggested for under-water vision, but so far none have promised success.

Speed in submarines is a feature much sought after. Due to limitations of electric power, size of battery, etc., the submerged speed cannot at present be brought to a high figure. In modern submarines this varies from 9 to 11 knots, and this speed can be maintained for only one hour. If a slower speed is used the distance covered will be greater, but the maximum submerged radius of a modern submarine will probably be 100 miles at 5 knots.

Surface speed offers greater possibilities of development and increase, and along these lines all countries are now working. For several years 14 knots has been considered about a maximum, but with development in oil engines, greater speeds have been attained. Some of the English submarines in service make 16 knots, and some German submarines 17 or 18 knots. At the present time, however, both in this country and abroad, there are submarines building of 20 and 21 knots speed. In such vessels steam or Diesel engines are used. None of these fast vessels are in service, so that it remains for the future to show whether they will usurp the place of the torpedo-boat destroyer. The radius of action of a modern submarine on the surface varies from 2,500 to 5,000 miles, so it may be seen that long trips are possible.

All modern submarines carry torpedoes as their essential armament. In general, it is foreign practice to fit two or more tubes in the bow and two in the stern, while in our Navy we have adhered to a bow arrangement with two to four tubes grouped there together. To fire these torpedoes the periscope must, of course, be exposed and the vessel herself pointed at the enemy. It is not always realized, and so may be worth noting, that the torpedo itself is really a small submarine boat with high-powered engines. With modern torpedoes speeds of from 35 to 40 knots are obtained, with ranges up to 4,000 yards or more. Submarines, however, usually fire their torpedoes at ranges of from 600 to 2,000 yards. In addition to torpedoes submarines nowadays generally carry one or two small guns, and the use to which such guns may be put has been brought out clearly in the present war.

It is often thought that a submarine is a mass of machinery and that the life on board is simply existence in a whirl of shafts, levers, etc. A submarine is indeed filled with machinery and the crew are mechanical experts; but the quarters provided for the crew are as good as those on a torpedo boat. Bunks are furnished for all the men; electric ranges are installed for cooking food, and everything is done to make these vessels habitable and comfortable as far as possible for comparatively long cruises. For example, fuel, supplies, fresh water, etc., can be carried by modern submarines to make a cruise of 5,000 miles. This is a fact not generally realized.

A modern submarine—and this applies to our own as well as other navies—is a vessel displacing about 450 tons on the surface and 600 tons submerged. The surface speed is from 13 to 15 knots and the submerged speed from 10 to 11 knots. Such a vessel would be 150 to 160 feet long. Within the boat a certain space is taken by ballast tanks, for, as I have stated, water is admitted to destroy the buoyancy and to permit the vessel to submerge. The remainder of the space is given up to engines, electric storage battery and motors, torpedoes, crew's quarters and central operating compartment. In this last-named space are grouped the important means for controlling the vessel—the controls for flooding ballast tanks, the air connections for blowing water out of them, the wheels for controlling the steering rudders and the diving rudders, and the periscopes.

When the boat is to submerge all the deck gear is taken down and all openings in the hull are tightly closed before water is admitted to the

tanks. When the boat is running on the surface of the water rail stanchions are fitted, a small bridge is rigged, radio masts are hoisted, and the submarine becomes a small cruising vessel.

In our Navy we have kept pace with the world in submarine development. Most of our submarines are of about the size and type described in the foregoing; but in addition we are building at present one large submarine of about 1,000 tons surface displacement and of about 20 knots speed, and appropriations for two more such vessels were recently made by Congress. This program parallels those of England, France and Germany, which, in addition to their submarines of 400 or 500 tons surface displacement, are also building submarines of from 1,000 to 1,100 tons and of from 20 to 21 knots speed.—"Engineering News."

GEARED MARINE STEAM TURBINES.

Mr. J. Hamilton Gibson, Wh. Ex., M. I. N. A., engineering manager of Messrs. Cammell, Laird & Co., Birkenhead, read a very interesting paper before the members of the Foremen's Mutual Benefit Society of the Birkenhead and Liverpool district. Mr. Roy M. Laird presided.

Mr. Gibson said the steam turbine, excellent as it is in many respects, especially for large powers and high-speed vessels, has certain well-defined limitations. It is a grand motor at full speed; but its efficiency falls off very rapidly if for any reason it is slowed down. Then it becomes what is popularly known as a "steam-eater." When once the stop valve is opened the steam rushes through the turbine at a speed averaging 1,000 feet per second, or 700 miles per hour—a hurricane is a gentle breeze in comparison. And if the turbine is to make the best use of this steam, it must revolve at such a speed that the circumferential velocity of the blades is not less than half the steam speed. No use closing down the throttle, the steam will not move an inch slower on that account; in fact, it gets through the turbine all the faster, because there is less of it to crowd through. To slow down a reciprocating engine, you merely bite off small mouthfuls of steam, imprison it in successive closed cylinders, and expand it just as slowly and deliberately as the pistons will permit. But there are no closed spaces or pistons in a turbine, once the stop valve is opened there is a clear run to the condenser through myriads of passages, and the steam will fly through at a speed fixed by the immutable laws of nature, whether it is an ounce or a ton. To increase the power and reduce the speed we must not only provide a sufficient number of openings in the first ring of blades, but we must also provide a large number of successive rings of blades, increasing in size to allow for expansion, and in order to extract the last ounce of energy from the steam particles before we allow them to escape. It means increasing the size and, therefore, the weight of the turbine, and that cannot always be conveniently done. In short, we sometimes reach a point where, if the turbines are to revolve slow enough for practical use they would have to be made so big and heavy that they would sink the ship. On the other hand, if it is decided to keep down the size of the turbines, and run them faster, the propeller would have to be made so small, and would revolve at such a tremendous "lick," that it would merely tear a hole in the water—the blades would lose their grip—and the propulsive effect would be practically *nil*. For vessels of high speed, 20 or 30 knots or over, the turbine may be connected direct to the propeller shaft, and results can be attained equal or superior to the best reciprocating-engine practice. In fact, when we get beyond speeds of 25 knots, which is about the practical limit for reciprocating engines, the turbine rapidly overhauls the reciprocator in all round

efficiency, and has driven it completely off the field, as in all modern war vessels, where high speed is a paramount consideration.

But if we take the merchant steamship tonnage of the world, it will be found that only about 2 per cent. of it comprises vessels of over 20 knots. The remaining 98 per cent., including ocean-going tramps and intermediate liners, are still "hacking through," most of them at 10 to 12 knots, by means of the good old piston engines. The limit of economy has long ago been reached in these engines by quadruple and even quintuple expansion, to say nothing of super-heaters, feed heaters, and patent packings. It was, therefore, high time that the marine engineering faculty turned its attention to the question as to how the steam turbine, which had so revolutionized the performances of high-speed vessels, could be adapted for use in this vast fleet of steamers, which comes below the 20-knot line. This includes some 1,500 new vessels built annually, totalling about 3,000,000 tons, so that the matter is well worth consideration. Obviously some form of gearing would be required to link the naturally fast-running turbine to the large, efficient, slow-turning propeller. In view of the large powers to be transmitted, great importance was attached to the strength of the gear wheels, the size of the teeth, and various methods of carrying the gearing in shock-absorbing frames, or even providing the wheels with built-up or laminated flexible teeth. When gearing was first proposed, old engineers shook their venerable heads in fear and doubt as they recalled the geared engines of half a century ago, and remembered the numerous troubles and breakdowns of those early days. But here was quite a different problem. The first marine engines were ponderous and slow, making only 10 or 20 revolutions per minute, and had to be geared up to suit the propeller. The steam turbine, running at 2,000 or 3,000 revolutions per minute, requires to be geared down, and that makes all the difference. Moreover, the old gear wheels had to be built up with large wooden teeth morticed into the rim, carefully shaped and trimmed and fitted by hand. Today we have machine tools of the utmost precision that not only cut, but actually generate the theoretically correct form of the teeth to within a thousandth of an inch error. The original inventor and perfector of the marine steam turbine took little or no part in the paper battles of the gearing. Sir Charles Parsons is not the man to advertise his ideas "for daws to peck at" before he has demonstrated the facts to his own satisfaction. How did he proceed? Whilst the controversy was raging he quietly bought an old tramp steamer, removed the triple-expansion engines, and fitted in their place a set of geared turbines. Nothing else was altered—same boilers, same shafting, same old propeller even, running at about 70 r.p.m. and giving a speed of about 9 knots. A typical tramp. A toothed wheel, 8 feet 4 inches in diameter, was fitted in the original shaft, and gearing into this wheel were two pinions 5 inches diameter, that on the starboard side being driven by a high-pressure turbine and the port pinion by the low-pressure turbine. The turbines ran at about 1,400 revolutions per minute, the gear ratio being thus 20 to 1. Here it will be well to compare the performance of this vessel—the *Vespasian*—with the results obtained with her original triple-expansion reciprocating engines: (1) Twenty-five tons' weight of machinery was saved; (2) under normal full-speed steaming conditions an increased speed of 1 knot was obtained, with the same coal consumption; (3) at 65 revolutions per minute the saving in coal amounted to 15 per cent., and at full speed, or 70 revolutions per minute, the saving was 19 per cent.; (4) this means that for the same power only five-sixths of the boiler power is needed, or, in other words, one boiler out of six could be saved—no small achievement. How does it come about that we get the same power and energy out of the imprisoned demon in a small enclosed cylinder as we used to get from a mighty engine with its great cranks, connecting rods and pistons? It's all a matter of speed!

The great point to keep in mind is this—and the late Robert Humphries used to lay great stress on it whenever he was asked to add any complication to his engines, which, in his opinion, reduced their simplicity without adequate return—that the main and sole object of any engine, however big and powerful, is merely to revolve a certain shaft and turn a propeller so many times a minute, and that, other things being equal, we get the same horsepower from a 3-inch shaft revolving 3,000 times a minute as we do from a 12-inch shaft making 50 turns a minute. Now, the essence of the design of a geared-turbine installation may be stated thus: A vessel of a given size and speed is best propelled by a screw of a certain diameter revolving at a certain number of revolutions per minute. Then, according to the weight and space that can be allowed for the machinery, we can design a set of turbines that shall revolve six times or twenty times as fast as the propeller, and introduce pinions and gear wheels to correspond. The beauty of the arrangement is that we are free to choose the best speed of rotation for the propeller, and at the same time the most efficient speed of rotation for the turbines. Another great advantage is this, that the speed of the ship can be reduced considerably if required, without adversely affecting the efficiency of the turbines, which, of course, means economy in fuel consumption. These turbines are connected direct to the propeller shaft, and must perforce revolve at the same speed; they never, or hardly ever, revolve fast enough to give the best economical results, and their efficiency falls off rapidly as the vessel reduces speed. The first thing that strikes one in the geared turbine is the remarkably small pitch of the teeth. The majority of engineers imagined, and naturally so, that enormously strong and heavy teeth would be required to transmit the enormous powers in modern ocean liners, amounting to some 15,000 H.P. per shaft in some cases. The normal standard pitch for all large powers is only .583 inch (less than 5/8 inch), which means that the teeth are less than 5/16 inch thick. This fine pitch, as we have seen, conduces to smooth running; but it is imperative that the wheel and pinion bearings be mostly rigidly held at the absolute right centers, and the standard of workmanship must be the highest attainable. The correct geometrical form of tooth has received very careful consideration, and the standard form for all gears is now an involute (as opposed to the cycloidal shape), with a short addendum and large radii in the roots to conserve the strength of the teeth. The involute form enables all gears to be cut with the same standard hob, and ensures that all wheels and pinions, of whatever size, shall gear together correctly. Moreover, if it is desired to vary the oil clearance between the teeth by opening or closing the wheel centers a few thousandths of an inch, this can be done without affecting the efficiency of the gears in the slightest degree. It may be taken as an axiom that if the gear wheels and pinions are absolutely concentric, are cut absolutely true, are fitted with absolute correctness both as regards centers and parallelism, and are, of course, properly lubricated, the gears will run at all speeds and powers in dead silence. The earlier gears were admittedly imperfect, and, therefore, the noise was distinctly in evidence, sometimes rising to a continuous droning note, particularly if the teeth were fitted too close, with little or no oil clearance. When a turbine is connected directly to the propeller shafting no thrust block is required, as the steam, pressing aft on the turbine blades, is balanced by the propeller thrust pressing forward. But a geared turbine is not connected direct to the propeller shaft. Its spindle terminates in a claw-coupling, which engages a similar claw-coupling on the pinion shaft. The geared turbine must, therefore, be independently balanced, just like a turbo-dynamo, and this is accomplished in the usual way by balance cylinders on the rotor, all self-contained within the turbine casing. We must provide separately for the propeller thrust, by fitting the usual thrust block secured firmly to the ship's keelsons.

Thrust blocks of the sector type were fitted in our two-geared turbine vessels recently completed for the passenger service between Buenos Ayres and Monte Video. When the first boat went on trial there were not wanting Jeremiahs who foretold dire disaster. The idea of attempting to run vessels of 5,000 H.P. on a single thrust collar. But, for once, the prophets were mistaken, the end justified the means, and these blocks ran from the very first without the slightest trouble. Only the other day I saw a report from the engineer of one of the boats on her voyage to the River Plate. He said, "Thrust bearings ran quite cool, with the chill not off." I think it may be said that all future geared-turbine jobs will necessarily be fitted with the "Michel" thrust, and I see no reason why it should not apply equally well for reciprocating engines now that the principle is established; but here again it will take time, probably years, to persuade superintending engineers that the old-fashioned multi-collared thrust block has at last been superseded by something better, and that the "Michel" thrust, like the geared turbine, has come to stay. It has taken shipowners a long time to make up their minds to adopt geared turbines in long-distance ocean-going liners. The pioneer vessel *Vespasian* ran her demonstration voyages from the Tyne to Rotterdam as far back as 1909, but it was less than two years ago when the first order for a geared-turbine ocean liner was placed. Now, most of the big companies are having geared vessels built, and already the Cunard Company's *Transylvania* has made one or two eminently successful voyages. There is always a tendency among shipowners to "wait and see," and when they see that their rivals are able to run vessels as big as their own on 15 to 20 per cent. less coal, with a smaller engine and stokehold complement, and can carry more cargo, they will not be slow to follow suit. Moreover, as compared with a triple-expansion job, the weight of machinery is 10 to 12 per cent. less, whilst the saving in space occupied is about 25 per cent. It may be considered by some very unsportsmanlike, but the geared turbine engine has set itself resolutely against the practice of "racing." It doesn't matter how light the ship, or how rough the sea, whether the propeller is revolving in the water or whisking in mid-air as the vessel throws her stern up, there is no appreciable variation in the revolutions, and the life of the tail shaft and the comfort of all on board is increased in consequence. We can therefore predict with confidence a boom in geared-turbine steamers for ocean traffic before we are very much older; and it behooves all enterprising shipowners and shipbuilders to be in the swim.—"The Steamship."

CLEANING OF CONDENSER TUBES.

Zeitschrift f. d. gesamte Turbinenwesen, No. 15, 1915.

The municipal electric works at Bielefeld, Germany, made an experiment to clean condenser tubes of lime deposits by means of hydrochloric acid. Mixtures varying in strength from 1 to 2 to 1 to 10 were used for the metals under test, *i. e.*, brass, tin, copper, wrought iron and cast iron. The action of the diluted acid on the bright surfaces of the parts to be cleaned was small, excepting cast iron, which produced considerable quantities of hydrogen gas. Therefore, it is recommended to paint the cast-iron water chambers to protect them against the acid. By further trials the quantity of acid solution of 1 to 5 was ascertained that was needed to clean a single tube. To keep the diluted acid in constant circulation in the horizontal type of condenser built by M. A. N., the suction pipe of a small centrifugal pump was connected to the inlet branch of the condenser. The discharge pipe of pump was connected to

a cover plate of the condenser, to which was also connected a vent pipe which terminated under the surface of a water tank. The condensers in question contained about 258 cubic feet water. They were charged for 3 hours each with 3,792 pounds of hydrochloric acid of 22 degrees Baumé, and subjected for another 20 hours to the action of the acid contained in the remaining solution until the formation of gas at the vent pipe had practically ceased. The fine mud in the tubes was washed out by a strong stream of water which discharged into the sewer. By analysis it was found that the deposit contained 83 per cent. of carbonated lime with small additions of organic and inorganic substances. The cost of the acid for dissolving the hard lime coating in this case for each condenser amounted to .2918 cent per square foot cooling surface. The acid cost is based on a price of 51.64 cents per hundred. The cooling surface was about 7,000 square feet.

THE PURCHASE OF COAL ON SPECIFICATIONS.

At an informal meeting of the committee appointed by the American Society for Testing Materials, held in New York in May, 1914, in connection with a proposed form of "Specification and Contract for the Purchase of Coal for Use in Steam Power Plants," the following questions were discussed:

1. Ash content and B.t.u. value have been and are widely used as factors for establishing the quality of coal bought under specifications, but the general conclusion has been reached that regular B.t.u. determinations on every sample are unnecessary where all the coal comes from the same region and bed. In such case the B.t.u. value varies proportionately with the ash content, which, therefore, becomes a measure of heating value. When coal comes from different beds or regions, then B.t.u. values and analyses are of value.

2. Very few specifications in use make any mention of the clinkering qualities of coal, although this matter is of great importance and should be covered in all specifications. The fusing temperature of ash is used to measure this, but its method of determination should be further investigated before definite recommendations can be made.

3. Moisture specifications were also discussed. Neither the "as received" nor the "dry" basis has proved altogether satisfactory. Moisture in coal is variable; its exact determination in any shipment is difficult, because of uncontrollable losses, and its amount is largely accidental. To use the "dry-coal" basis may give inaccurate values when coals of different nature are compared. In fact, a satisfactory way of handling the moisture question has not yet been evolved.

4. Alternate methods of analysis are not desirable; a standard specification should always specify one standard method. The question of weights was also discussed, but no conclusions were arrived at.

As a general conclusion, it is believed by many chemists, engineers and others, that after the buyer of steam coal has decided on the description of coal he desires and what is best adapted to his use, there are only two items necessary, as regards analysis, in making up specifications, that is, the percentage of ash and the fusing temperature of the ash.

A standard percentage of ash of a given kind of coal (field or seam) insures a standard B.t.u. value; any change in ash percentage makes a corresponding change in B.t.u. value. The right ash-fusing temperature means no clinkers, and good combustion results if the coal is handled properly.

Where smoke laws are to be observed it may be necessary to specify also a maximum volatile content of the coal, although even here it would

generally be advisable and economical in the end to alter furnace and boiler conditions so that higher volatile, cheaper (usually) coals could be used.

Simplicity, equity and practicability should be the characteristics of all specifications for the purchase of coals.—F. R. Wadleigh, in "Coal Age."

GOOD AND BAD LUBRICANTS.

By G. Basil Barham, A. M. I. E. E.

Whatever an economist might advise or do, no engineer would select a lubricant on account of its lasting qualities alone. To him they would be quite a secondary consideration; he would require to be assured that it would keep cool the moving parts on which it was to be used before he would go into the question of whether it would or would not last longer than some other lubricant he was using or had under consideration.

The first essential of a lubricant, from an engineering point of view, is that it should possess a low and constant coefficient of friction. If the friction is small the heat generated will be small. Providing the lubricant used will float the parts and allow a film to be maintained, it only remains that the characteristics which tend to set up friction by resisting the relative movement of the parts, should be as few and as inappreciable as possible.

It is not easy, however, with all lubricants to maintain this film; with some it is not an easy matter to ensure an adequate supply passing to the point where it is required. Some lubricants will squeeze away and leave parts starved; others, of the composite variety may give up one or more of their constituents and leave the "filling" to clog and bind, and ultimately cut the surface of the parts. Further, if it were only a matter of a low coefficient of friction, practically any clean oil, whether animal, vegetable or mineral, would answer the purpose, provided it was fresh and in good condition. But any attempt to lubricate machinery for any length of time with either animal or vegetable oils would have disastrous results, as all organic oils undergo chemical changes, and either turn rancid, or thicken and gum. The only oil that can be used for lubricating purposes with any good and sustained result is a mineral oil, and unless this has been chosen, and treated specially by processes dependent upon expert knowledge not only of oils, but also of the purposes for which each is intended, the results are not likely to be satisfactory. It is emphatically not a case of "any old oil will do," where high-speed electrical and other machinery is in question; it is a question of comparative expense and expediency. Engines and generators cost more than lubricants, and it must be pointed out that oil, no matter how excellently it be blended, has its limitations, and there is a question as to whether, in view of modern developments, it is not bad engineering to use oil at all for lubricating purposes.

GREASES AND NON-FLUID OILS.

It is a fact that whilst types of prime movers have been standardized, and dimensions and proportions resulting from wide experience have been adopted for prime movers, one feature of design, *i. e.*, engine lubrication, has not kept pace with other developments. It is not too much to say that quite 80 per cent. of engine troubles are due to defective or improper lubrication. The other twenty per cent. can be about equally divided between careless or ignorant operation and inadequate proportions of work-

ing parts. At one time it was the practice to use oil lavishly in the cylinders of vertical condensing engines and with slide valves of the piston type, with the result that considerable damage was done to the boilers, and as soon as the bad effects of such oiling were made apparent a certain school of engineers straightway turned to the other extreme, and adopted the plan of running these parts without any oil or grease, trusting to the lubricating effect of the steam. Even then it is necessary to use oil on the flat slide valves of intermediate and low-pressure cylinders, so that the method is really of little or no use in preventing the access of oil to the feed water. When it is remembered that the globules of oil are so minute, much of the oil having been carried over in the form of vapor, that water only moderately emulsified can be allowed to stand in settling tanks for months and skimmed at regular intervals, without the whole of the oil content rising to the surface, it will be seen how difficult it is to deal with the trouble by means of filters of loofaa, straw, Hessian, or a combination of any of these with other substances. Chemical grease extractors have been introduced, some of which have been more or less successful, but as a general thing the difficulty has been so great that many power users have adopted the use of solid lubricants, and hold the opinion, to which many are being converted, that in some form these will be the lubricants of the future.

It is claimed that they increase the efficiency of oiling and minimize waste, and there is no doubt that, if of high grade, soap-solidified oils and greases can be successfully used on a number of parts which have to stand heavy duty. At the same time objections can be advanced against both these lubricants themselves and the methods in which they are generally used.

In the majority of cases solid or semi-solid lubricants are made by working up animal fats or vegetable butters with soap and water, or by thickening mineral oils of thin body but extreme viscocity with soap. The soaps used are of the ordinary lime, soda or lead types, and it must be pointed out that it is not an easy matter to prevent an excess of caustic soda being present. During use this is being converted into carbonate of soda, and there is a danger of the bearings being cut in consequence. Such greases frequently contain free fatty acids which attack the metal parts on which they are used; one of the least troubles experienced with such a lubricant would be the scoring of metal parts passing through stuffing boxes, as rods or valve stems, and also of the glands. Further, when thickened mineral oils are used, there is a liability for the oil content to be squeezed away, leaving the soap body behind it in the bearing, where it not only hardens but forms a nucleus to which any abraded metal particles and dirt adhere. In this way a gummy mass is formed which soon coats the moving parts, increasing friction and leading to ultimate cutting. Where such lubricants are used in boxes it is common practice to fit these with brass pins which rest in the part in motion. Should friction increase beyond the normal, and heating be set up, the theory is that these pins become heated also and cause the grease round them to flow to the journal. Should a bearing lubricated in this way run very hot through neglect, and escape notice, in a very short time the whole of the grease will have run through, and thus allow the brass pins to work down between the shaft and the brass or the cap of the bearing and so grind up, cutting both shaft and bearing.

THE ADVANTAGES OF NON-FLUID OILS.

The same objections cannot, however, be urged against high-grade non-fluid oils. They have all the advantages of soap lubricants but none of their disadvantages, and in addition they possess the property of adhering to metal surfaces with a force which is considerably above that possible

with fluid oils. They are all of high viscosity and can only be fed drop by drop. In that they prove economical, as with ordinary oil a greaser can and frequently does squirt oil with a lavish liberality not only on the part needing it, but also on any parts adjacent. It is not to be supposed that this slow feeding is a disadvantage even where a bearing has run hot, as, owing to its clinging properties, it films immediately on reaching the moving part and so forms an ideal lubricant. Non-fluid oils, also, will not gum, and they can be used without risk of clogging in central distribution systems provided the oil tubes are of sufficiently large internal diameter to permit of the oil flowing.

In practice it has been found that one pound of non-fluid oil of high quality is equal in lubricating effect to one gallon of high-grade fluid oil, and according to the average prices ruling the saving effected in direct cost by using such lubricants would be about 65 per cent., or more, according to the quality used.

The extremely low average coefficient of friction possessed by high-grade non-fluid oils has been proved by numbers of independent tests, and such oils are being largely used with high-speed machinery, being mechanically fed to the various parts. But where the adoption of non-fluid oils is contemplated, it must always be remembered that a lubricant which would suit a certain class of machinery might be of little use for another. As has been said, the art of economically employing a lubricant consists mainly in the application of precisely that quality of unguent which is best adapted to that particular place on each machine or each part of a machine on which pressure of lubricated surfaces of widely differing amount is found, and, above all, applying it in the best possible way.

THE USE OF GRAPHITE.

Of recent years the claims of graphite to be considered the ideal lubricant have been supported by a large and increasing number of engineers. It is common knowledge that when used for such purpose graphite should be of such quality and fineness as to give a perfectly smooth and even veneer or coating to the parts. The danger is that an impure or carelessly prepared grade might be used, which would carry into the bearings or cylinders such impurities as are naturally associated with graphite, as sand, clay, mica or talc. The essentials of good lubricating graphite are that it should be amorphous and of extreme softness. It should have neither luster nor brilliancy, and a heaped quantity of it should not reflect light, nor show bright particles when examined with a powerful lamp. The color is not so important; dense blackness does not necessarily show purity any more than a feeling of smoothness when rubbing a sample between the thumb and finger proves fineness. For example, it may be mentioned that by a special electrical process graphite can be made of such a degree of sub-division that the particles cannot be seen under an ordinary microscope. Ordinary graphite contains particles of about 1/350 of an inch in diameter, but electrically-prepared graphite has no particles estimated to be larger than 1/330,000 inch in diameter. It is, of course, this finely divided graphite which is most generally used for lubricating purposes, and from the results of which the value of graphite as a lubricant will be judged.

On examination under a high-powered microscope any metal, no matter how carefully ground, polished or burnished, will be found to show many small irregularities, which are the real cause of friction. It is the scraping of these, one over another, and the constant cutting or wearing, which is so productive of hot boxes, cut valves and cylinders. The thin, tough particles of graphite attach themselves to, and build up these irregularities, filling up the hollows and forming a thin but practically indestructible veneer-like coating of extreme smoothness. When formed,

under no circumstances short of the introduction of some foreign body which would cause scoring before the graphite began its equalizing work, could the metal surfaces come into actual contact with each other. The film being indestructible, no sudden hammer effect, such as takes place when the load is suddenly switched off a large generator and the armature shaft drops from its floating position, can do damage which might be done were oil used as a lubricant. Oil can easily be hammered out, but there is no known means whereby graphite can be knocked out of position in a bearing.

It is noteworthy that flake graphite may be introduced to cylinders, may pass into feed water, may even be purposely placed in the boilers without it doing the slightest injury. As a matter of fact, its presence is an advantage rather than a detriment, as the flakes becoming attached to the plates, prevent scale from taking hold, and so considerably lessen pitting and scaling. Also the heat transfer will not be affected as the substance is a particularly good conductor. For ordinary purposes graphite may be mixed with non-fluid oils, or even with soap-base greases with advantage, but obviously for valve and cylinder lubrication of condenser engines graphite of the purest possible quality should be used by itself or else the old trouble of separating the oil from the feed water would recur.

Graphite may be applied in the following manner: Whenever valves or cylinders are overhauled, graphite mixed with vaseline may be applied to the surfaces, as this will ensure a general distribution. Graphite can be introduced on starting up, through an oil cup or indicator pipe. It can be put in in a dry state, but a better plan is to float it in water and apply it in exactly the same way as lubricating oil is applied. If at any time there should be slight squeaking, or a bearing should start to warm up, a little graphite and water will effect an instant cure.—"Cassier's Engineering Monthly."

SUCCESSFUL MANUFACTURE OF RADIUM.

The cost of one gram of radium metal produced in the form of bromide during March, April and May of the present year was $36,050, I am informed by Dr. Charles L. Parsons, in charge of the radium investigations of the Bureau. This includes the cost of ore, insurance, repairs, amortization allowance for plant and equipment, cost of Bureau of Mines coöperation, and all expenses incident to the production of high-grade radium bromide. When you consider that radium has been selling for $120,000 and $160,000 a gram, you will see just what the Bureau of Mines has accomplished along these lines.

The cost of producing radium in the small experimental plant during the first few months of the Bureau's activities was somewhat higher, but not enough to seriously affect the final average.

The public, however, should not infer that this low cost of production necessarily means an immediate drop in the selling price of radium. The National Radium Institute was fortunate in securing, through the Crucible Steel Co., the right to mine 10 claims of carnotite ores belonging to them, and this was practically the only ore available at the time.

Since then new deposits have been opened, but these are closely held, and according to the best judgment of the experts employed by the Bureau of Mines the Colorado and Utah fields, which are much richer in radium-bearing ores than any others known, will supply ore for a few years only at the rate of production that obtained when the European war closed down the mines. The demand for radium will also increase rapidly, for the two or three surgeons who have a sufficient amount of this element to entitle them to speak from experience are obtaining results in the cure of cancer that are increasingly encouraging as their knowledge of its ap-

plication improves. A few more reports like that presented to the American Medical Association at its recent San Francisco meeting and the medical profession as a whole will be convinced of its efficacy. Under all the circumstances that have come to my knowledge it does seem to me that it behooves the Government to make some arrangement whereby these deposits, so unique in their extent and their richness, may be conserved in the truest sense for our people, by extracting the radium from the ores where it now lies useless and putting it to work for the eradication of cancer in the hospitals of the Army and Navy and the Public Health Service.

The 10 carnotite claims being operated at Long Park, Colo., by the National Radium Institute have already produced over 796 tons of ore averaging above 2 per cent. uranium oxide. The cost of ore delivered at the radium plant in Denver has averaged $81.30 per ton. This included 15 per cent. royalty, salary of Bureau of Mines employees, amortization of camp and equipment, and all expenses incident to the mining, transportation, grinding and sampling of the ore.

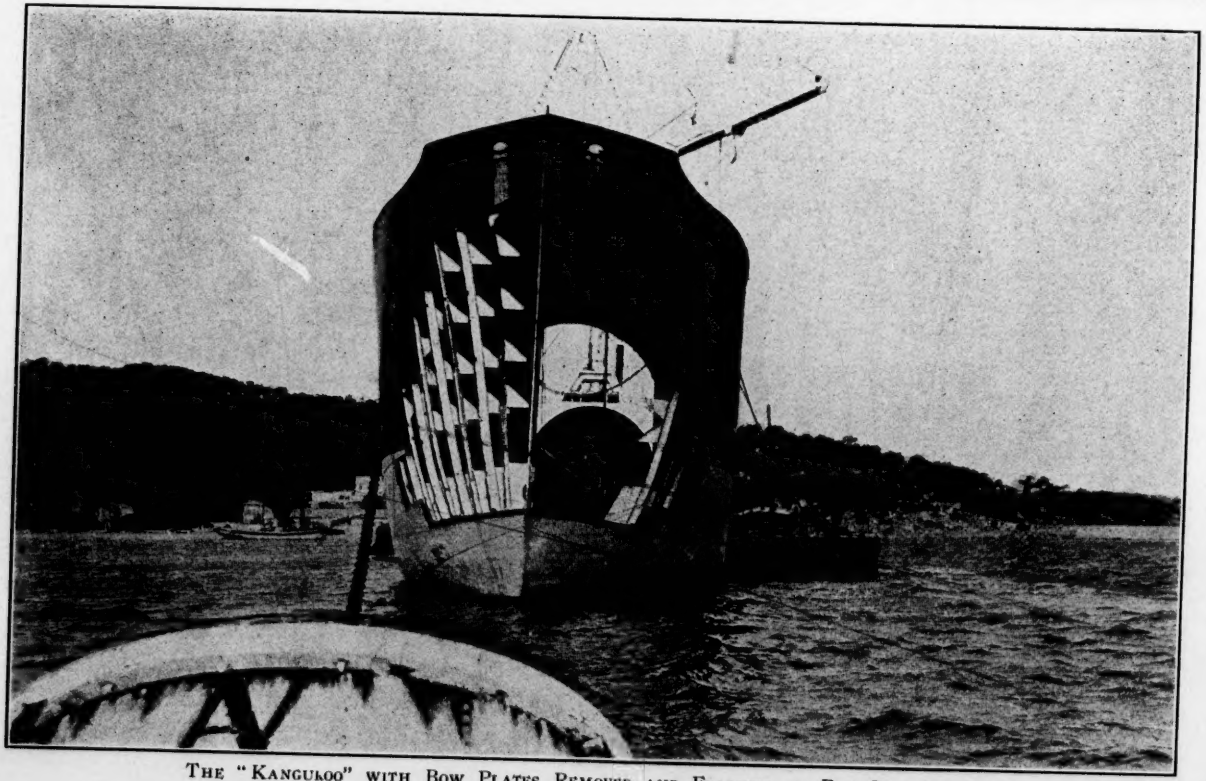
A concentrating plant for low-grade ores has been erected at the mines and is successfully recovering material formerly wasted. Grinding and sampling machinery has been installed at Denver and a radium-extraction plant erected in the same city. The radium plant has now a capacity of three tons of ore per day, having been more than doubled in size since last February. Before that time the plant has been run more or less on an experimental scale, although regularly producing radium since June, 1914. To July 1, slightly over three grams of radium metal has been obtained in the form of radium barium sulfate, containing over one milligram of radium to the kilogram of sulfates. The conversion of the sulfates into chlorides and the purification of the radium therefrom is easily accomplished and with very small loss of material. Unfortunately, however, special acid-proof enamel ware, obtainable only in France, has not been delivered of sufficient capacity to handle the crystallization of the full plant production, so that a little less than half the output, or, to be exact, 1,304 milligrams of radium element have been delivered to the two hospitals connected with the National Radium Institute. The radium remaining can be crystallized at any time from neutral solution in apparatus already installed, but the greater rapidity and efficiency of production of this very valuable material by the methods used have decided the Bureau of Mines to await the completion of apparatus now being built before pushing the chloride crystallization to full capacity.

The average radium extraction of all ore mined by the National Radium Institute has been over 85 per cent. of the amount present in the ore as determined by actual measurement. The amount present in the ore has been found, in fact, to be essentially the same as the theoretical amount required by the uranium-radium ratio. The extraction figures for the last five carloads of carnotite treated has shown a recovery of over 90 per cent. in each case.

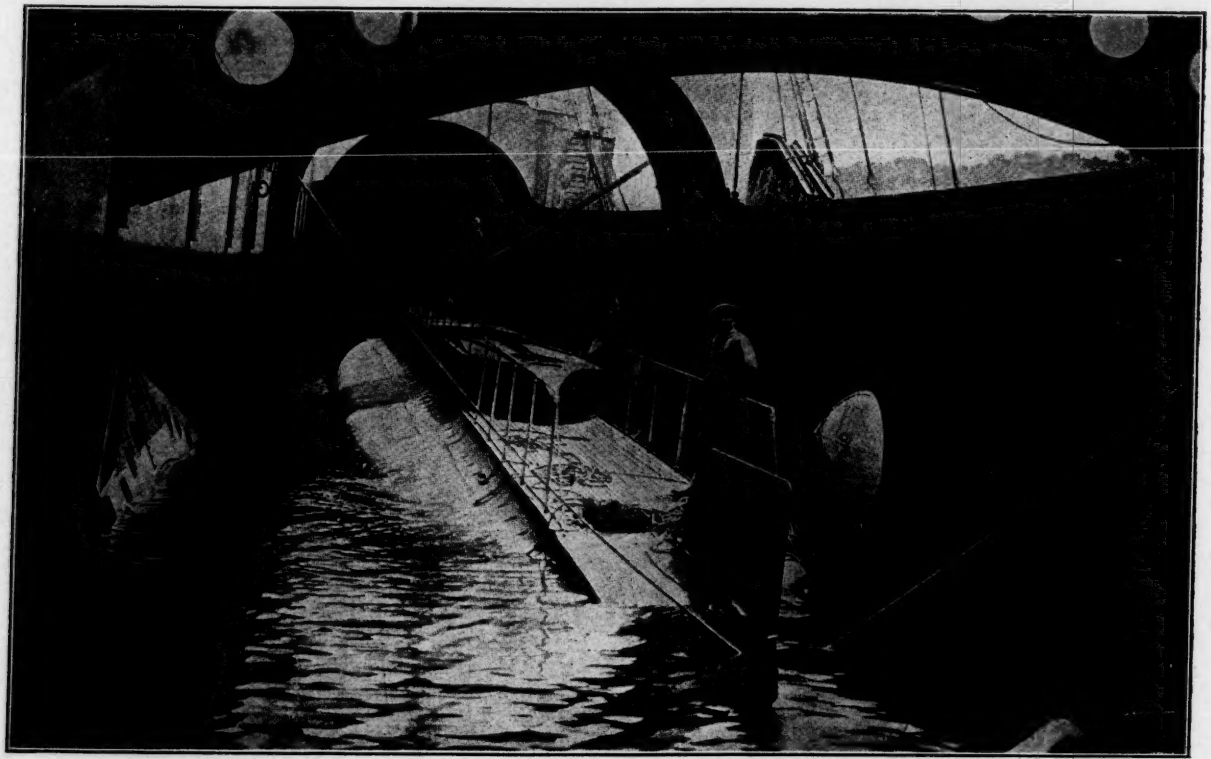
A bulletin giving details of mining, concentration and methods of extraction is being prepared by the Bureau of Mines and will be issued early in the fall.—Extract from U. S. Commerce Report No. 175, July 28, 1915.

ADAPTING A SUBMARINE TRANSPORTER FOR GENERAL CARGO.

The announcement that Messrs. Norton, Lilly & Co. have chartered the *Kanguroo* to load at New York for Bordeaux is an interesting sidelight on the demand for tonnage at present, since the *Kanguroo* was designed by Messrs. Schneider & Co., Le Creusot, for delivering submarines to foreign owners. The vessel, however, has the advantage that when not being used for this purpose it may be considered as a single-deck cargo boat,



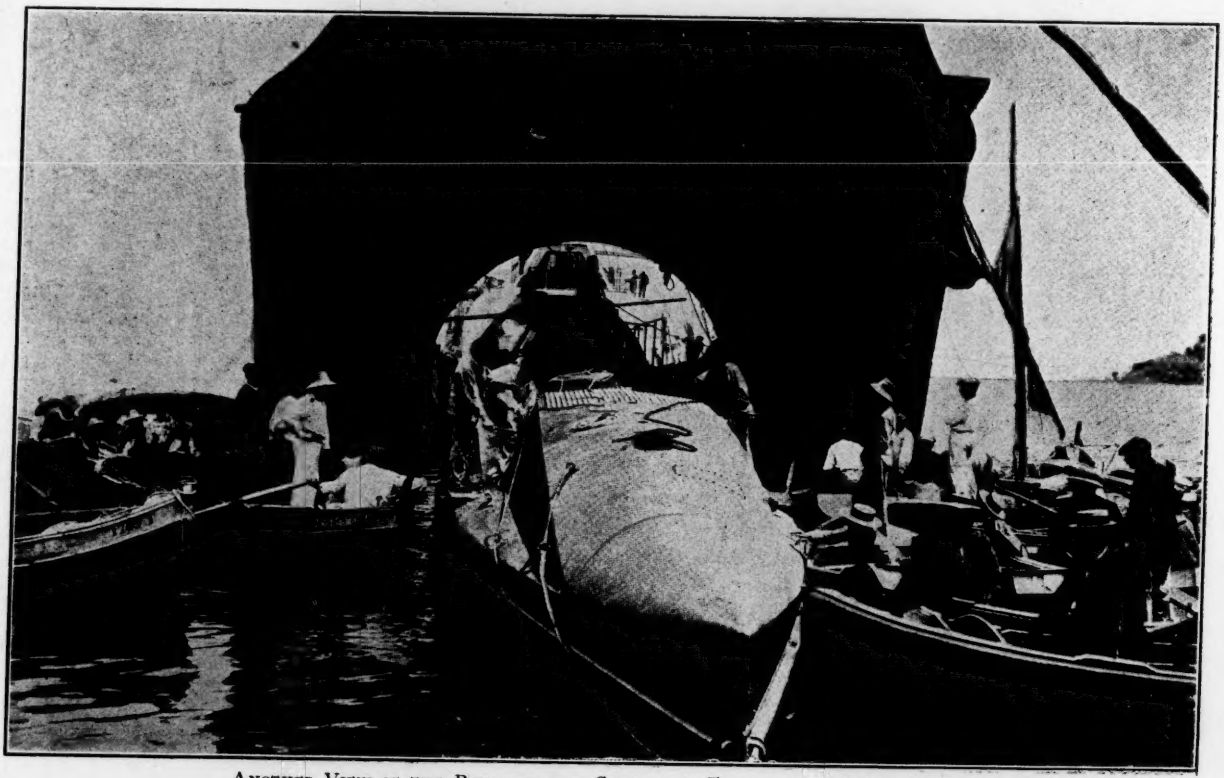
THE "KANGUROO" WITH BOW PLATES REMOVED AND FRAMING ON PORT BOW CLEARED.



SUBMARINE BERTHED AND AWAITING THE RAISING OF THE VESSEL TO CLEAR WATER OUT OF HOLD.

SUBMARINE BERTHED AND AWAITING THE RAISING OF THE VESSEL TO CLEAR WATER OUT OF HOLD.

SUBMARINE PREPARING TO ENTER THE "KANGUROO."



ANOTHER VIEW OF THE BOW, AND THE SUBMARINE ENTERING THE "KANGUROO."

although it is obvious that the compromise effected in the design would hardly make the vessel a paying one, excepting in the existing high freight rates.

The *Kanguroo* has been employed as a submarine carrier on few occasions. The first two voyages were when Messrs. Schneider & Co. sent Laubeuf submarines to Callao for the Peruvian government, and last year she was employed by the Fiat San Giorgio, of Spezia, to deliver a Laurenti submarine to Rio de Janeiro.

The principal dimensions are: Length, extreme, 305 feet; breadth, 39 feet; draught (mean), 19 feet; displacement, 5,540 tons; carrying capacity, 3,830 tons; tonnage, 2,493 gross, 1,720 net.

The vessel is built entirely of steel and is propelled by triple-expansion engines of 850 H.P., giving a speed of about 10 knots. The ship is divided into three main parts, namely: (i) the after portion, containing the propelling and auxiliary machinery, accommodation for crew and so on; (ii) a large hold, 190 feet long, and capable of accommodating a submarine; and (iii) the fore part of the ship, specially designed for allowing the submarine to pass into the hold and containing the main tanks for raising and lowering the vessel.

This large hold consists of a double shell, with a hatchway covered by hatches removable by means of a traveler bridge. The space between the two skins is constructed for water ballast in the lower part and has air chambers in the upper portion.

In the bow of the ship there is a tunnel, the lateral walls of which are watertight. The space between these walls and the shell consists of three water-ballast tanks, one at the bottom and two higher up the sides. At the extremity of the tunnel, which is separated from the hold, strictly so-called, is a watertight double-swing door. The portion immediately in front of the entrance of the tunnel consists of sections which can be removed in order to admit the submarine.

The *Kanguroo* with bunker coal, has her trim so altered by the filling of the water-ballast tanks aft that the stem rises completely out of the water. The bow plates which cover the tunnel referred to are removed, and the double-swing doors at the extremity are opened, thus giving free access to the hold. The water tanks in the fore part of the ship are next filled. This has the effect of making her sink at the bows until the bottom of the hold is lower than the draught of the submarine. When this is completed and the vessel is trimmed satisfactorily the submarine enters the hold through the tunnel. Wooden chocks and stays are placed in the hold for the submarine to rest on, and when all is completed the trim of the *Kanguroo* is again altered by emptying the ballast-tanks in the fore part of the ship, whilst still maintaining communication between the hold and the sea. As soon as the stem of the ship is sufficiently out of the water the swing door is closed, the bow plates are replaced, leaving the submarine high and dry, resting on the chocks referred to. The trim of the vessel is then adjusted for proceeding to sea. These operations are here illustrated, but it will be seen that for certain types of cargo the large free hold is particularly advantageous. Moreover, there are cases, such as in the timber trade, where the facilities afforded by the open bow may be taken advantage of.—"Shipbuilding and Shipping Record."

ANOTHER VIEW OF THE BOW, AND THE SUBMARINE ENTERING THE "KANGUROO."

AUXILIARY NAVAL VESSELS.

CLASSIFICATION OF NAVAL VESSELS—DESCRIPTION OF THE DESTROYER TENDER "MELVILLE."

The great variation in the composition of groups and types of vessels in the naval establishment of a first-class power may, perhaps, be conceived by scrutinizing the list appended below, comprising, it is believed, all the units as they would appear in active service:

A.—Fighting Ships.—(1) Battleships of the first line. (2) Battleships of the second line. (3) Armored cruisers. (4) Cruisers of the first class. (5) Cruisers of the second class. (6) Cruisers of the third class. (7) Destroyers. (8) Torpedo boats. (9) Submarines. (10) Gunboats.

B.—Coast and Harbor Defense Ships.—(1) Monitors. (2) Coast defense ships.

C.—Dispatch Ships.—(1) Scouts. (2) Converted yachts.

D.—Auxiliary Ships.—(1) Supply ships. (2) Hospital ships. (3) Oil fuel ships. (4) Colliers. (5) Transports. (6) Mine layers. (7) Mine sweepers.

E.—Miscellaneous Ships.—(1) Tugs. (2) Coal barges. (3) Ash lighters. (4) Water barges. (5) Ammunition lighters. (6) Freight lighters. (7) Floating workshops. (8) Floating derricks. (9) Garbage lighters. (10) Ferry boats. (11) Mud scows. (12) Dredges. (13) Diver barges.

The vastness of the scope for administration, operation, design and construction covering such a complexity of units, will be conceded when a little thought is bestowed on the fact that each type of the vessels enumerated represents an individual design made to fulfill a given purpose and to perform a certain predetermined work during operations.

Under the name "Supply Ships" as given in the list, there are to be found two separate more or less distinctive classes, viz.: A. Tenders for submarines. B. Tenders for destroyers.

Of the former type of recent construction the submarine tender *Fulton* was described in the issue of July, 1914, of this journal, and as representative of the latter class the present article will deal with the destroyer tender *Melville.*

It is a well-known fact that the dimensions of destroyers or submarines are as yet not of such proportions as to render them independent in their actions for any length of time, when cut off from access to supply depots. It might properly be mentioned that as a result of the limited capacity of such vessels, together with the very exacting demands placed upon them in service, the construction of tenders or supply ships was essentially born.

SERVICE CHARACTERISTICS.

As the service intended to be performed by ships coming under this class of vessels is to supply munitions of war, provisions and stores, the interior arrangements are made primarily with a view to meet this purpose. There are also arrangements made on board to care for a large number of sick or otherwise incapacitated.

Among the supplies which a tender will be called upon to provide we find the following: A. Air, compressed and carried in flasks. B. Ice and refrigerated supplies. C. Light and electric current. D. Fresh water. E. The output from machine shops for necessary repairs. F. Hospital service (for which provision of 38 beds has been made).

Besides machinery and output for the supply of foregoing necessities, storage is provided for torpedoes, mines and ammunition, meats, stores and provisions.

GENERAL FEATURES.

The general appearance of the new destroyer tender *Melville,* with its two masts and straight stem, somewhat resembles an ocean liner, but becomes distinctly military in the light of the batteries, consisting of eight 5-inch 51-caliber rifles and two 3-pounder saluting guns.

The general dimensions and data pertaining to the ship are as follows: Length between perpendiculars, 400 feet; breadth, 54 feet 5½ inches; depth, 20 feet; displacement (normal), 7,150 tons; oil fuel carried, 900 tons; speed, in knots, 15; total horsepower, main turbines, 4,000; number of shafts and screws, one; type and number of boilers, two B. & W.; total heating surface, square feet, 7,000; three generating sets, 100 kilo-

watts each, 125 volts; total complement of officers and crew, 254; name of builders, New York Shipbuilding Company; launched, March 4, 1915; state of finish, 90 per cent.; cost of vessel, complete, $1,310,000 (£268,000).

GENERAL HULL ARRANGEMENT.

There are three principal decks, consisting of main deck, second and third deck. Below these decks forward is placed a platform deck which extends aft as far as possible and also partially amidships. Below the platform deck is the hold, divided into suitable compartments, among which are trimming tanks, hold space, stores and space for any provisions. On the deck spaces above are to be found special storerooms, cold storage rooms and magazines, officers' quarters aft and crew space forward. On the main deck are located three deck houses. In the forward deckhouse are arranged, besides the commanding officer's cabin and office, executive offices and navigating officer's stateroom. Similarly in the after deckhouse there are located the junior officers' staterooms and the flotilla commander's office and cabin. Within the deckhouse placed amidships there are situated the engine-room hatchway, coppersmith and blacksmith shops, a foundry, the general storekeeper's and paymaster's office and a trunk for the smoke pipe, together with various other smaller compartments.

MACHINERY ARRANGEMENT.

The driving power in this ship is developed by steam turbines, while in the submarine tender *Fulton* the corresponding power is produced by a Diesel engine.

The engine room is divided below the main deck into three compartments of which the center compartment constitutes the turbine room, while each wing compartment constitutes an auxiliary engine room. There are located in the starboard engine room three ice machines, the auxiliary condenser, and above on a gallery, the generators with switchboard. In the port engine room below the gallery are to be found the main condenser, the main air and circulating pumps and feed tanks, and on the gallery four double-effect evaporators, together with the necessary pumps.

Forward of the engine compartment is the boiler compartment, where are placed, besides the boilers, fuel-oil settling tanks, pumps and blowers.

The capacity of the evaporating plant is about 25,000 gallons for each twenty-four hours, and each of the three ice machines will yield 3 tons of ice every twenty-four hours. The three turbo generators are each of 100 kilowatt capacity.

There are placed in the machinery spaces numerous other auxiliaries, such as the main and auxiliary feed pumps, fire and bilge pumps, lubricating-oil pumps, evaporator feed and fresh-water pumps, fuel-oil supply pumps and burner pumps. The distillers are placed at a higher level in the engine-room hatch.

The turbine machinery is of Parsons type and consists of two separate turbine units, of which the high-pressure unit is placed on the starboard side and the low-pressure unit on the port side of the ship.

The transmission of power from turbines to the propeller is effected by means of a Westinghouse mechanical reduction gear, consisting substantially of a pinion on each turbine shaft meshing with a gear wheel attached to the center shafting driving the propeller. The propeller revolves at a speed of 110 revolutions per minute, while the turbines run at 1,400 revolutions. The speed of transmission is thus reduced in a ratio of 140 to 11, or nearly thirteen times.

The gearing is of the double-spiral type with the teeth of each cut in the opposite direction. Each pinion transmits 2,000 horsepower, and, being of the same diameter, revolves at the same speed, viz., 1,400 revolutions per minute. The gear-wheel center is made of cast iron, the rim of

cast steel and the shaft of mild-steel forging, while the pinions are made of rather high-grade steel forgings and the pinion-driving shafts of chrome-nickel steel. The angle of the spiral is about 30 degrees and the width of face is 16 inches for each single gear, making a total width of driving face of 32 inches with 40 tooth contact points with a contact pressure of 562 pounds.

The general advantages claimed for transmission of the propulsive power by means of reduction gearing as compared with straight turbine drive are:

1. About 15 per cent. increase in the economy of coal consumption.
2. Average reduction in the weight of the machinery about 15 per cent.
3. The reduction in the size of turbine rotors, which is of practical advantage in handling, as well as general reduction in the size of turbines.

To meet the requirements for successful operation, the gearing must be durable, practically noiseless, with the transition of pressure from tooth to tooth without shock.

The bearing supports of the pinions for mechanical gearing are made sometimes rigid and sometimes with floating arrangements, both of which have given satisfaction. The Westinghouse gearing is provided with a hydraulic floating arrangement for each pinion, and is now made for several United States vessels.—"International Marine Engineering."

HALL'S SYSTEM OF REFRIGERATION FOR SHIPS.

The accompanying illustrations show the latest design of refrigerating machinery for ships, which is manufactured by Messrs. J. & E. Hall, Ltd., Dartford Iron Works, Kent.

This firm was founded by John Hall in 1785, that is, 130 years ago, and they have been pioneers in mechanical progress. Their machines are on CO_2 (carbonic anhydride) system, for which they claim the following special advantages: Although dense carbonic anhydride (CO_2) will not support life, it is, in the quantities used in a refrigerating machine, quite innocuous. The whole charge may be (and has been experimentally) allowed to escape in an engine room without ill effects or inconvenience being experienced by the attendants. Ammonia (NH_3) and sulphurous acid (SO_2), on the other hand, are actively poisonous gases; a very small percentage in the air is inimical to life, so that any considerable leakage is likely to have serious consequences, and many fatal accidents have been attributed to this cause. The harmless nature of CO_2 permits of a safety valve being fitted to relieve any excessive pressure which might be created through neglect or oversight. Carbonic anhydride (CO_2) is tasteless and inodorous, and has no effect, detrimental or otherwise, upon any goods, even the most delicate and easily-tainted foodstuffs, with which it may come in contact. It is, in fact, the harmless gas used for the "aeration" of mineral waters, wines and beer. CO_2 has no affinity for metals, consequently the materials that are most suitable can be adopted for the various parts of the machine. For example, copper is used for the condenser coils of marine machines because of the corrosive action of sea water upon iron. These copper coils are indestructible and retain their efficiency and their intrinsic value after many years of service. Whilst the carbonic anhydride (CO_2) machine compares favorably in economical working with any other system, it has the advantage of employing a cheap and easily-obtainable refrigerating medium. For example, the cost of a complete charge of CO_2 for a machine of 24 tons ice-making capacity is about £5, compared to £112 for a charge of ammonia.

Referring to the diagram, Fig. 2, the principle will be readily under-

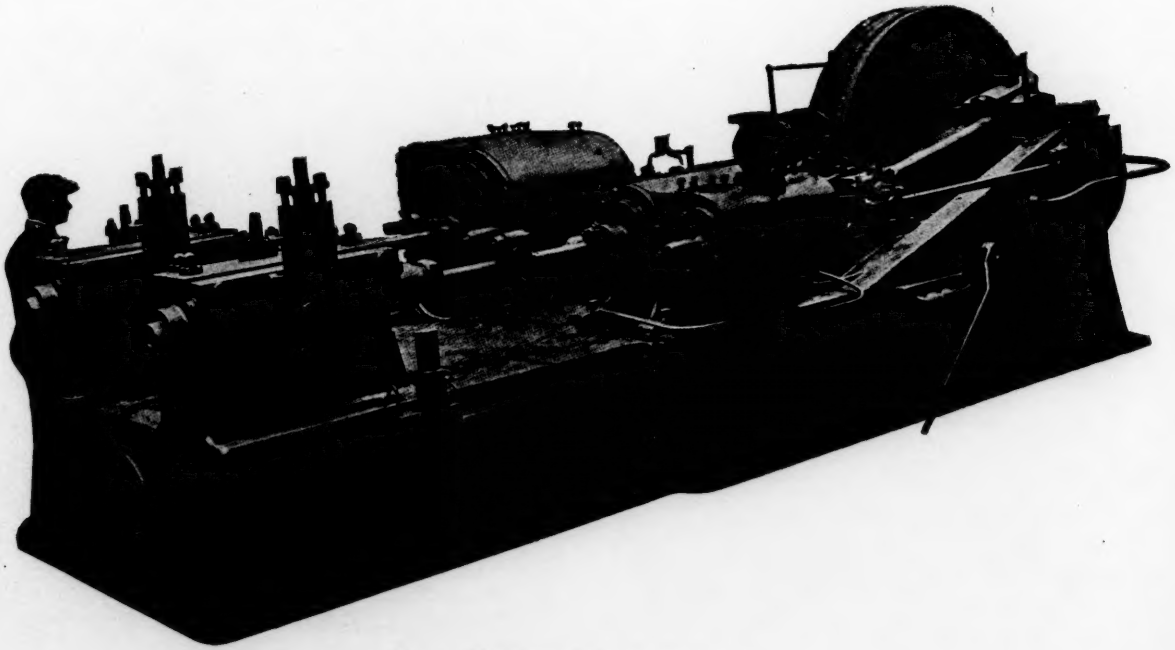


FIG. 1.—HORIZONTAL DUPLEX MACHINE.

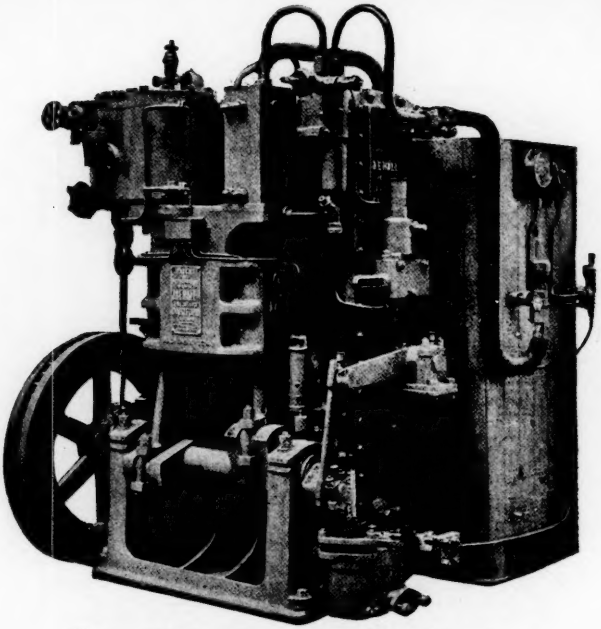


FIG. 3.—VERTICAL SINGLE MARINE-TYPE MACHINE.

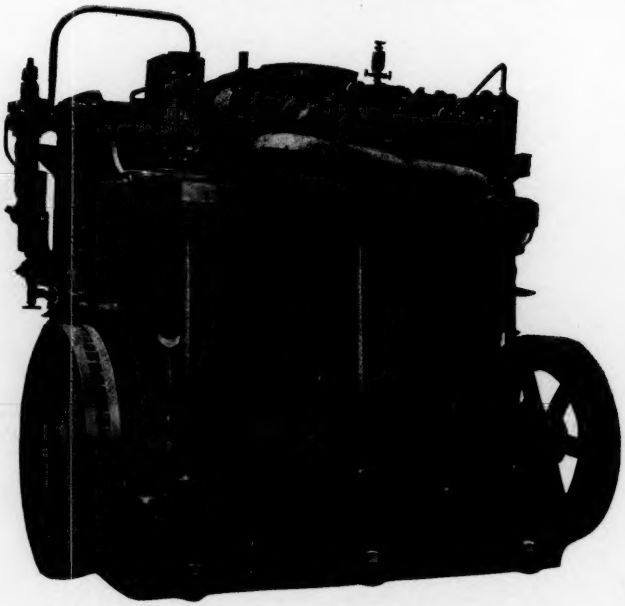


FIG. 4.—VERTICAL DUPLEX MACHINE.

stood. The CO_2 machine is one of that type of refrigerating machines wherein the refrigerant during the cycle of operations undergoes a change of state, from gas to liquid and from liquid to gas, the transformation being accompanied by the liberation and absorption of a quantity of heat many times greater than that due to the mere change of temperature of the refrigerant. This type of refrigerating machine consists essentially of the following three parts, shown diagrammatically in the illustration, Fig. 2: The compressor, in which gas drawn from the evaporator is compressed; the condenser, consisting of coils in which the hot gas delivered from the compressor is cooled and liquefied by the action of the cooling water; the evaporator, consisting of coils in which the liquefied CO_2 is evaporated by heat abstracted from the material to be cooled, producing any degree of temperature that may be required down to 80 degrees F. below freezing point. The simplest conception of the refrigerating machine is that it is a heat pump, *i. e.*, heat is abstracted at the "low level" of the cooling duty performed and discharged at the "high level" of the condensing water. The cycle of operations is as follows: On the suction stroke of the compressor piston a charge of gas is drawn from the evaporator and on the return stroke the gas is compressed and discharged

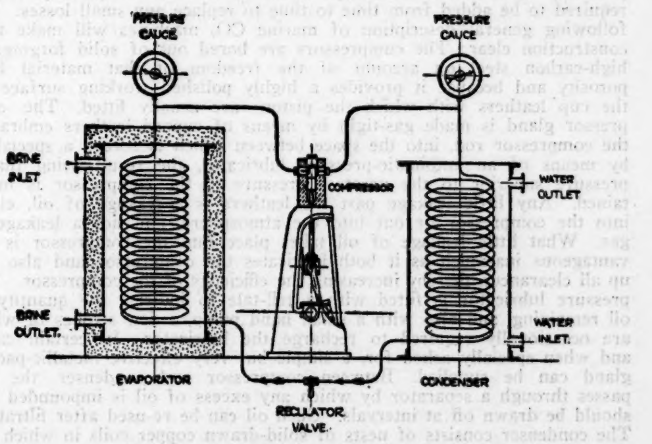


FIG. 2.—DIAGRAM SHOWING WORKING.

into the condenser coil at a pressure sufficient to cause liquefaction, this pressure depending directly on the temperature of the cooling water. The gas enters the condenser coils at a high temperature and during its passage through the coils is cooled to a temperature within a few degrees of the cooling water circulating over the surface of the coils, with the result that the gas is liquefied, the latent heat of liquefaction passing into the surrounding water. The liquid CO_2 then passes from the lower terminals of the condenser coils through the regulating valve to the evaporator coils, where evaporation takes place at a temperature sufficiently below that of the medium to be cooled to allow of a reasonably rapid interchange of heat. The evaporator coils thus perform the reverse function of the condenser coils, the heat required to evaporate the liquid CO_2 being absorbed from the surrounding brine solution or other medium, which is consequently lowered in temperature. The outlet terminals of

the evaporator coils are connected to the suction of the compressor, the CO_2 passing in the form of a gas from the evaporator to the compressor, and thus completing the cycle. The action of the evaporator of a refrigerating machine is analogous to that of a steam boiler, the liquid CO_2 taking the place of water as the medium to be evaporated and the surrounding solution of brine replacing the fire as the source from which the heat required to effect evaporation is supplied. Just as water under atmospheric pressure boils at a temperature of 212 degrees F., and under a pressure of 100 pounds per square inch at a temperature of 337 degrees, so liquid CO_2 under a pressure of 21 atmospheres boils at a temperature of zero F., and so on for other pressures. Under atmospheric pressure CO_2 evaporates from the solid at the extremely low temperature of 120 degrees below zero F., or 152 degrees below the freezing point of water. The production of so low a temperature does not, of course, come within the scope of the commercial refrigerating machine, but this property has frequently been made use of in the laboratory for experimental purposes in connection with the liquefaction of the more permanent gases. The charge of carbonic anhydride originally put into the machine is used over and over again, going progressively through the processes of compression, condensation and evaporation. Thus a small quantity only is required to be added from time to time to replace any small losses. The following general description of marine CO_2 machines will make their construction clear: The compressors are bored out of solid forgings of high-carbon steel on account of the freedom of that material from porosity and because it provides a highly polished working surface for the cup leathers with which the pistons are usually fitted. The compressor gland is made gas-tight by means of cupped leathers embracing the compressor rod, into the space between which is forced a special oil by means of an automatic-pressure lubricator, the result being that a pressure superior to the greatest pressure in the compressor is maintained. Any little leakage past the leathers is a leakage of oil, either into the compressor or out into the atmosphere, and not a leakage of gas. What little leakage of oil takes place into the compressor is advantageous inasmuch as it both lubricates the compressor and also fills up all clearances, thereby increasing the efficiency of the compressor. The pressure lubricator is fitted with a tell-tale to indicate the quantity of oil remaining, and also with a small hand pump, a few strokes of which are occasionally required to recharge the lubricator. In certain cases, and when specially asked for, a simple but very effective metallic-packed gland can be supplied. Between compressor and condenser the gas passes through a separator by which any excess of oil is impounded and should be drawn off at intervals. Such oil can be re-used after filtration. The condenser consists of nests of solid-drawn copper coils in which the gaseous CO_2 is liquefied. They are strapped rigidly together by means of stays and bolts or rivets, all of bronze. Each length of pipe is specially brazed to the next to form a continuous coil without joints. The condenser coils, round which sea water is circulated, are usually contained in the base of the machine or in an independent cast-iron tank strongly ribbed. The evaporator consists of nests of wrought-iron hydraulic pipes electrically welded into long lengths, and inside them the liquid carbonic anhydride evaporates. The heat required for evaporation is usually obtained either from brine surrounding the pipes, as in cases where brine is used as a cooling medium, or else from air or water surrounding the pipes, as in cases where it is required to cool air or water direct. A regulating valve is placed between the condenser and evaporator for adjusting the quantity of the liquid carbonic anhydride passing from the condenser. In order to enable the compressor to be opened up for examination of valves and piston without loss of carbonic anhydride it is necessary to fit a stop valve on the suction and delivery sides, so as to confine the carbonic anhydride to the condenser and evaporator. It is,

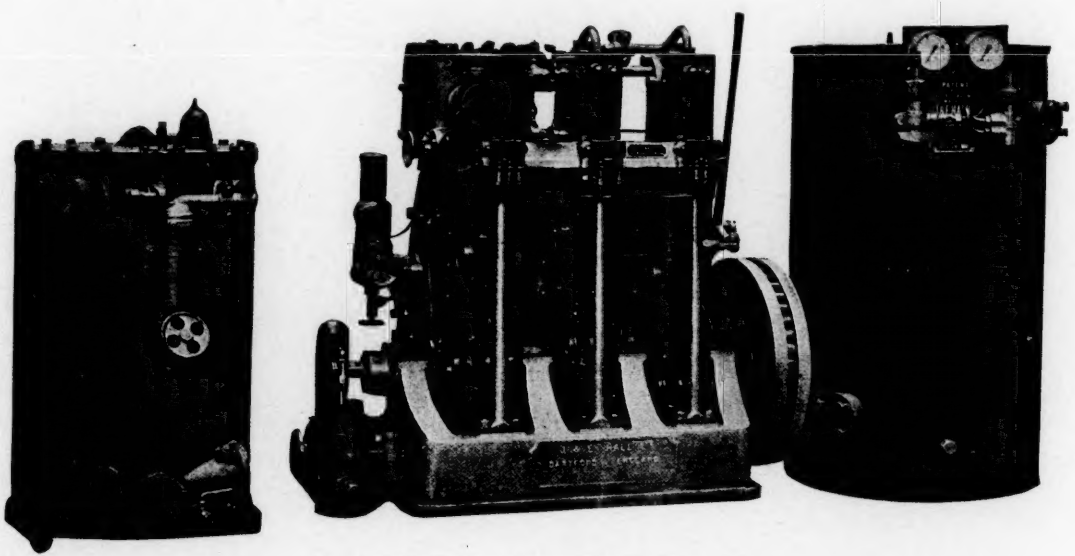


FIG. 5.—NAVAL-TYPE STEAM-DRIVEN MACHINE.

of course, possible for a careless attendant to start the machine again without opening the delivery valve. In such case an excessive pressure would be created in the delivery pipe, from which there would be no outlet. To provide against this danger a safety device (see illustration) is adopted, consisting of an ordinary spring safety valve, at the base of which is a thin copper disc designed to relieve at a certain pressure, considerably below that to which the machines are tested. This disc is made perfectly gas-tight, which could not be effected by the spring safety valve alone, the latter only coming into play when the disc is ruptured. Great care is necessarily exercised in making the discs to provide against variation in strength, due to any want of accuracy either in the thickness or hardness of the copper sheets out of which the discs are made. Tightness of joints is obtained with entire success by the use of rings turned from solid-drawn copper tube which withstand the heat and yet have the necessary elasticity to ensure the joint being perfectly tight whether hot or cold. Nevertheless, as an additional precaution, every CO_2 joint throughout the machine is always made accessible. During manufacture, all parts of the machine subject to the pressure of the refrigerant are tested for strength by hydraulic pressure to three times the highest working pressure, and they are again tested for detecting any possible porosity by air pressure at 90 atmospheres while submerged in water. Owing to the comparatively small diameter of all parts, even in large machines, there is no difficulty in securing a very ample margin of strength.

The illustration, Fig. 3, shows the vertical single marine-type machine. This type of machine is made in three sizes, 7, 8 and 8A. The compressor, made from a solid forging of high-carbon steel, is driven through a two-throw crankshaft by a single-cylinder steam engine, the compressor and steam cylinder being mounted side by side on a strongly ribbed cast-iron frame. The back of the frame is arranged as a casing to contain the CO_2 condenser coils, which are of solid-drawn copper tube with brass stays and straps. The water-circulating pump, made entirely of gunmetal, is attached to the main frame and worked off a pin on the end of the crankshaft. A cast-iron casing containing the wrought-iron CO_2 evaporator coils is bolted to the back of the CO_2 condenser. This casing is insulated with granulated cork retained by tongued and grooved boards neatly finished. With the No. 8A machine an independent duplex steam-driven brine pump is provided for brine circulation. The No. 7 and No. 8 machines have the brine pump attached to the evaporator casing and insulated with it and driven off the crankshaft by means of a sway beam. Independent brine pumps can be supplied if required. A very large number of these machines have been supplied for preserving passengers' provisions, and almost every important line of passenger steamers have ships fitted with them.

The illustration, Fig. 4, shows a vertical duplex machine. This machine has its compressors carried on a strong cast-iron frame with forged-steel pillars. The steam engine is compound, and drives the compressors through a four-throw crankshaft, the crankshaft being carried in five main bearings. Crosshead guides are of the open type and very accessible. The two sets of condenser coils are of solid-drawn copper tube with brass straps and bolts, and are contained in separate compartments in the back part of the frame. Sea-water and brine-circulating pumps are of the independent steam-driven type. The two sets of electrically-welded wrought-iron evaporator coils are contained in a wrought-iron double casing, which can be specially made to suit the position in which it has to be placed.

The illustration, Fig. 1, shows a horizontal duplex machine. This is the type of machine fitted on large meat-carrying steamers and on some large fruit steamers. The steam surface condenser is arranged in the bed of the machine, with air and feed pumps driven off the crankshaft. The two sets of CO_2 condenser coils are each contained in a separate

rectangular cast-iron casing. The evaporator coils are contained in separate circular steel casings. The water-circulating pump is of the vertical duplex type.

The illustrations, Fig. 5, show the steam-driven naval-type machine. The frame is of cast iron, light but strongly ribbed, reinforced by polished steel columns in front. The compressors are made from solid forgings of high-carbon steel, and are of either the single-acting or double-acting type. The compressor rods are of nickel-steel, and the pistons are fitted with leather packing or metallic rings as required, similar packing being employed in the glands, which are fed with oil at a pressure above that below the piston by means of the differential lubricator. The crossheads are fitted with flat slipper guides, and the crankshaft of polished steel is carried in two, three or four main bearings according to the number of cranks. The sea-water circulating pump is of gunmetal and is driven by the crankshaft. The CO_2 condenser is of solid-drawn copper coils in a cast-iron casing, divided to facilitate overhaul in place. The evaporator coils, of steel or wrought iron, are contained in a similarly constructed cast-iron casing, which is well insulated and lagged with wood or galvanized steel. The brine pumps are independent, of the vertical duplex type with steam-driven machines and of the centrifugal type coupled direct to an electric motor with electrically-driven machines. Each plant is supplied complete with all necessary and usual accessories, also gas and brine-connecting piping between the various parts of the plant, brine-mixing tank, and a complete set of spanners and special tools.

—"Steamship."

THE SOUTHWARK-HARRIS DIESEL ENGINE.

SYNOPSIS.—A two-stroke-cycle engine with no scavenging or starting valves in the head, employing a stepped piston for both starting and scavenging and possessing unusual means of fuel control.

The impetus given the heavy-oil-engine industry in this country by the expiration of the original Diesel patents in 1912 has been marked particularly by the number of steam-engine builders who have entered this field. Some, choosing to follow foreign practice, are building under license from foreign firms with modifications to suit local conditions; others have developed what may be termed distinctly American designs. Among the latter may be mentioned the Southwark-Harris Diesel engine, built by the Southwark Foundry & Machine Co., of Philadelphia, from the designs of Leonard B. Harris.

This is a two-stroke-cycle type intended primarily for marine service, but also adapted to stationary work, the engine being somewhat simpler for the latter service, as no reversing is required. Because of the ingenious, yet simple and flexible, control for maneuvering, the marine type will be described.

Unlike most two-stroke-cycle Diesel engines, there are no starting nor scavenging valves in the head, the only opening being for the fuel atomizers, of which there is one to each cylinder in both marine and stationary types. There are two atomizer-actuating levers in the marine type, one for ahead and the other for astern; in the stationary type there is, of course, only one atomizer-actuating lever. This arrangement makes possible a very simple cylinder-head casting.

The pistons, as shown in Fig. 3, are stepped, the lower part serving as a scavenging pump besides acting as a guide in the place of a crosshead. The cylinders are in pairs, and each scavenging piston serves the adjacent cylinder of that pair through the passage A, valve V_2, manifold M and port D. This will be understood when it is remembered that the cranks

FIG. 1.—240-H.P. SOUTHWARK-HARRIS DIESEL ENGINE.

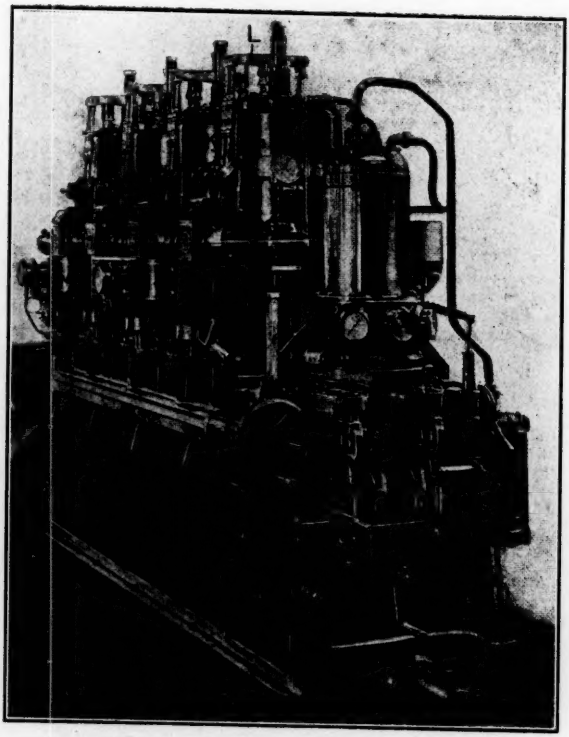


FIG. 2.—END VIEW, SHOWING PUMPS.

of a pair are set at 180 degrees. Therefore, when the scavenging piston of cylinder No. 1 is traveling upward, compressing the air in the scavenging cylinder, ports and manifold, the pistons of No. 2 are traveling downward, and when No. 2 working piston has uncovered its port D, the scavenging air, under a pressure of about 7 pounds, will rush in and force the spent products of combustion out through the exhaust ports E. The air-delivery valve of cylinder No. 2 prevents the scavenging air of No. 1 from being forced into the scavenging cylinder of No. 2 while its pistons are on the down stroke.

An unusual feature of this stepped piston is its use for starting the engine—a most important factor in marine work, as it avoids admitting cold starting air to the highly heated working cylinders and pistons when reversing and maneuvering. Moreover, as the area of the stepped piston is greater than that of the working piston, starting air of relatively low pressure, 175 pounds, can be employed. Since the starting is independent of the working cylinders, the fuel can be admitted to the latter while the starting air is still on. This will be found advantageous when starting under load, as the starting air can thus be used to help out until the momentum has been built up.

Of interest in this connection are the diagrams of Fig. 4. No. 1 is from the scavenging cylinder when starting with air, while No. 3 was taken simultaneously in the working cylinder. Line *a*, diagram No. 1, represents the first outward stroke, *b* the return stroke, and *c* the successive outward strokes until the starting air is shut off. It will be noted that after the first stroke, a pressure of only 30 pounds is required, owing to the power given back in the working cylinder by the expansion of the compressed air within it. Diagram No. 2 shows the normal working of the scavenging piston.

Starting and fuel-injection air is furnished by a two-stage compressor driven off the main shaft and having a control valve on the suction. The compressor delivers the high-pressure air for fuel injection directly to a steel air bottle mounted at the back of the engine frame. The starting air is supplied to the starting bottles through a reducing valve.

There is a separate fuel pump for each cylinder, making four in all in the engine shown. These are mounted at the end of the engine (see Fig. 2) and the stroke is varied by the governor.

A better idea of the operation of the fuel pumps will be gained by reference to Fig. 5. First, however, it will be necessary to revert to Fig. 1, which shows the pump shaft T_1 driven from the main crankshaft through the vertical shaft T and worm gears. At the end of T_1 is mounted a cam U, Fig. 5, which acts laterally upon the bell-crank levers W; these in turn work the pumps through the arms W_1, working in yokes on the pump stems. The fulcrum pins of the bell cranks are carried on laterally sliding plates V, the movement of which is effected through two worm splindles, each carrying a pair of right-and-left-hand worms meshing with sectors X. The upper worm spindle extends to the right and connects through gearing with the governor shaft, while the lower worm spindle extends to the left carrying the handwheel Y_1 and connecting through links and a rack (see Fig. 6) with the main control handle Y.

When the pointer of the main control handle is in the central, or "stop," position (see Fig. 1) the bell-crank levers W (Fig. 5) are separated so as not to be actuated by the cam U. Through the arrangement of links shown in Fig. 6, this position of the bell cranks is held ordinarily through the starting period. When the control handle is turned past the first notch to the running position the lower worm spindle is rotated and, by means of the sectors and slides, brings the bell-crank levers closer together, so that they are actuated by the cam U, and the fuel pumps are set in operation. The governor, now acting through the upper worm spindle, is able to control the position of the bell cranks and vary the

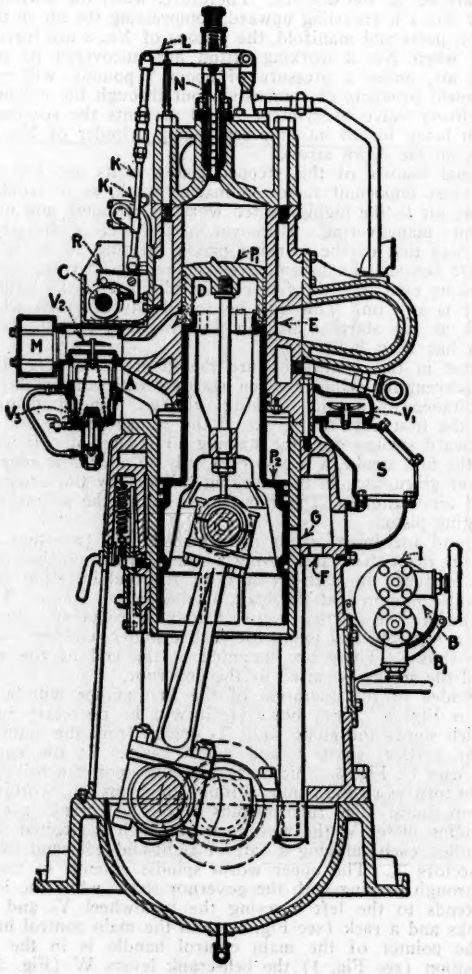


FIG. 3.—SECTIONAL ELEVATION.

P_1 is the main piston; P_2, the scavenging and air-starting piston; V_1, scavenging-air inlet valve; A, scavenging air outlet passage and starting-air inlet passage; V_2, scavenging-air delivery valve; M, manifold; D, scavenging-air inlet ports; V_3, the air-operated intercepting valve; O, outlet for starting air; S, silencer; F, vents; B, injection-air storage bottle; C, cam-shaft; R, atomizer-actuating rockers; K, push rods; L, atomizer levers; N, atomizer spindle; E, exhaust ports; I, injection air from compressor; B, bypass to starting bottles; K_1, bell crank.

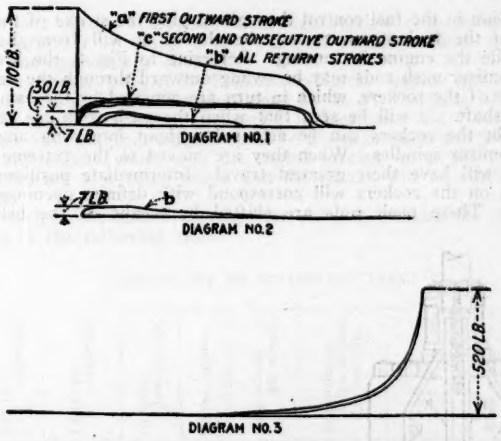


FIG. 4.—INDICATOR DIAGRAMS FROM WORKING AND STARTING CYLINDERS.

stroke of the pumps to suit the load. The small handwheel Y_1 permits manual control of the fuel without altering the position of the main control wheel Y. By this means the engineer is enabled to control the speed of the engine at will, and the governor will maintain control at this speed. This feature is especially useful in marine work when running through a heavy head sea with the engine racing.

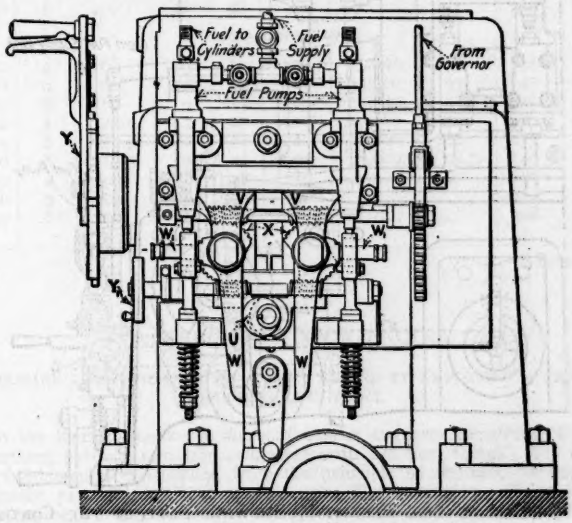


FIG. 5.—SHOWING FUEL CONTROL.

In addition to the fuel control through varying the stroke of the pumps, the lift of the fuel atomizers may be altered at will from the control wheel while the engine is running. Referring to Fig. 3, the lower ends of the atomizer push rods may be swung outward through the arc on the upper side of the rockers, which in turn are actuated by the cams on the main camshaft. It will be seen that when the push rods are at the extreme right the rockers can be actuated without imparting any motion to the atomizer spindles. When they are moved to the extreme left the atomizers will have their greatest travel. Intermediate positions of the push rods on the rockers will correspond with definite openings of the atomizers. These push rods are shifted by means of the bell cranks

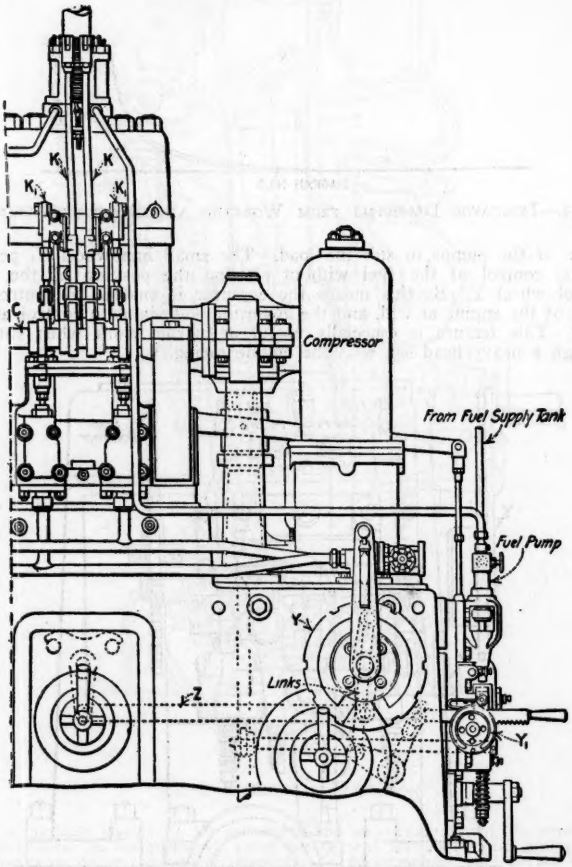


FIG. 6.—PARTIAL SIDE ELEVATION, SHOWING FURTHER THE CONTROL FEATURES.

shown, which in turn are operated through vertical rods connected with the horizontal bar Z (Figs. 1 and 6), also connected with the control handle. The operation is obvious.

A four-cylinder, 240-I.H.P. Southwark-Harris engine has just been installed in the yacht *Southwark*, owned by C. P. Vauclain, of Philadelphia. The *Southwark* is 98 feet overall, 16 feet beam and 7 feet draught, and on her first trial trip made a speed of about 10 miles per hour against the tide and a head wind, with the engine turning up at 225 r.p.m. Extensive tests are now being made, and the results will be available at an early date.

The principal dimensions, horsepower, weight, etc., of the sizes listed are given in the following table:

PARTICULARS OF STATIONARY TYPE.

Indicated horsepower.	No. of cylinders.	I.H.P. per cylinder.	Cylinder diameter, ins.	Stroke, inches.	Revolutions per minute.	Approximate weight without flywheel, lbs.	Weight per I.H.P., lbs.	Floor space, square feet.	Length overall, feet and ins.
120	2	60	9	13	300	14,000	117	21.6	6–9
240	4	60	9	13	300	25,000	104	34	10–2
360	6	60	9	13	300	35,000	97	45	13–7
225	2	112.5	12	21	200	27,000	120	51	9–8
450	4	112.5	12	21	200	47,000	104	80	15–4
675	6	112.2	12	21	200	66,000	102	110	21–0
400	2	200	16	28	150	.....	...	116	14–6
800	4	200	16	28	150	.....	...	180	22–6
1,200	6	200	16	28	150	.....	...	244	30–6
				MARINE TYPE.					
240	4	60	9	13	300	25,000	104	34	10–2
360	6	60	9	13	300	35,000	97	45	13–7
480	8	60	9	13	300	44,000	91.5	56.5	17–0
450	4	112.5	12	21	200	47,000	104	80	15–4
675	6	112.5	12	21	200	66,000	102	110	21–0
900	8	112.5	12	21	200	85,000	94.5	140	26–8
800	4	200	16	28	150	.....	...	180	22–6
1,200	6	200	16	28	150	.....	...	244	30–6
1,600	8	200	16	28	150	.....	...	308	38–6

—"Power."

A MERCURY VAPOR ENGINE.

INCREASING THE EFFICIENCY OF A HEAT ENGINE BY EMPLOYING A LIQUID OF HIGH BOILING POINT.

To the layman the word *thermodynamics* suggests something abstruse, something perhaps remotely connected with practical things. Yet one of the fundamental conclusions from the principle of thermodynamics is as intensely practical as it is unexpected. The maximum efficiency of a heat engine working between a temperature t_2 of the boiler and t_1 of the condenser is wholly independent of the working substance (steam, hot

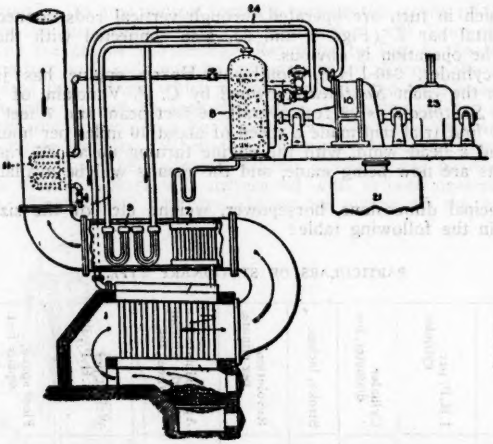


FIG. 1.—DIAGRAMMATIC VIEW OF APPARATUS TO GENERATE POWER.

1, mercury vapor boiler; 7, heater for liquid mercury; 8, condenser boiler; 9, superheater (steam); 10, steam turbine; 11, feed water economizer; 13, mercury turbine; 21, steam turbine condenser; 23, electric generator; 24, mercury vapor pipe.

air, gasoline, etc.), and depends solely on the temperatures t_2 and t_1. It is a common fallacy, among persons not well versed in these things, to suppose that for an engine working at a low temperature (as for example in the exploitation of the sun's radiation) some volatile substance, such as ether, would offer advantages over water. As already stated, this is not the case, the efficiency is wholly independent of the nature of the working substance, given a stated temperature of boiler and condenser.

Yet Mr. W. L. R. Emmet, working in the research laboratories of one

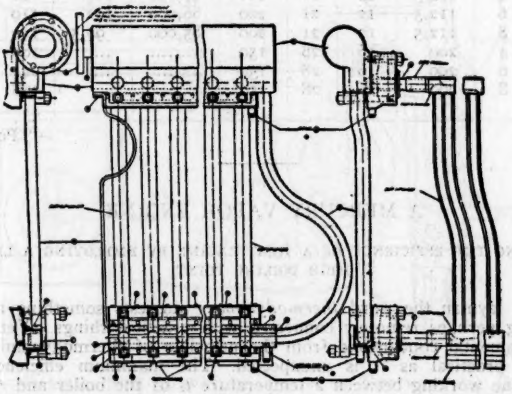


FIG. 2.—ASSEMBLY OF EXPERIMENTAL MERCURY BOILER.

of our most progressive industrial enterprises, has recently spent much time and effort developing an engine which uses the costly element mercury in place of water in the boiler. How is this to be harmonized with what was said above? The explanation is simple enough. It is true that the theoretical maximum efficiency of a steam engine working between, say, 677 degrees F. (the boiling point of mercury at atmospheric pressure) and 100 degrees F., would be exactly the same as that of an engine in which mercury vapor took the place of steam. *But*, a steam engine working at such temperatures would be impracticable, owing to the enormous pressure to which the boiler would be subjected. A mercury vapor engine can be, and has been, built to work effectively at the high temperature stated. And the higher the boiler temperature the greater the efficiency.

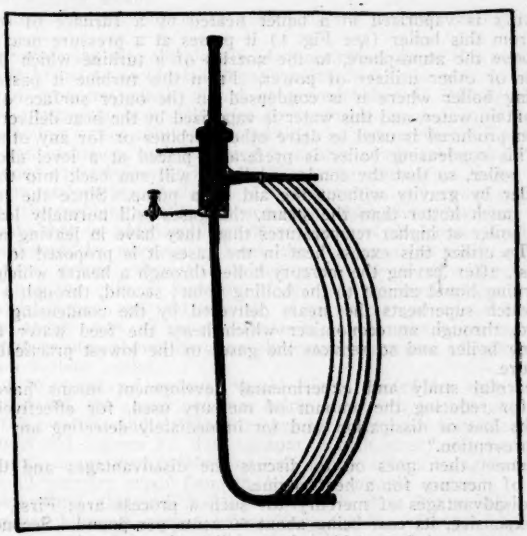


FIG. 3.—SECOND EXPERIMENTAL MERCURY BOILER TUBE.

To recapitulate, the nature of the working substance has no *direct* influence upon the efficiency of the engine. Indirectly it affects this efficiency, in so far as it determines, owing to practical considerations, the temperature at which the engine can be worked.

This, then, is one reason for Mr. Emmet's labors in perfecting a mercury vapor engine.

But there is another point to be considered. The steam engine, as commonly operated, is extremely wasteful in one particular: The combustion of coal furnishes a temperature of some 2,700 degrees F. The proper conditions are, therefore, presented for obtaining a high thermodynamic efficiency. But owing to the properties of steam a large amount of heat must be allowed to go to waste through the stack, and, though a temperature of 2,700 degrees F. is available in the furnace, actually only about 600 degrees F. (using a superheater) can, at the very best, be made use of in the cylinder. Now Mr. Emmet does not propose to work his

mercury vapor independently, but to intercalate it between the furnace and the steam boiler, so that all the advantages of the steam engine will be obtained as before, and the additional power furnished by the mercury vapor engine will be a net gain.

Whether the type of engine developed by Mr. Emmet is destined ultimately to figure prominently in industrial operations is perhaps at the present moment somewhat open to doubt. The prospect seems fairly promising, as will be seen from the description given below. In any case Mr. Emmet's engine presents many features of the very highest interest, owing to the peculiar conditions which have been faced and the ingenious manner in which the problems involved have been solved.

The method applied in his process is described by Mr. Emmet in a paper read before the American Institute of Electrical Engineers, as follows:

"Mercury is vaporized in a boiler heated by a furnace of ordinary type. From this boiler (see Fig. 1) it passes at a pressure near or not much above the atmosphere, to the nozzles of a turbine which drives a generator or other utilizer of power. From this turbine it passes to a condensing boiler where it is condensed on the outer surface of tubes which contain water, and this water is vaporized by the heat delivered, and the steam produced is used to drive other turbines or for any other purpose. This condensing boiler is preferably placed at a level above the mercury boiler, so that the condensed liquid will run back into the mercury boiler by gravity without the aid of a pump. Since the mercury vapor is much hotter than the steam, the gases will normally leave the mercury boiler at higher temperatures than they have in leaving a steam boiler. To utilize this excess heat in the gases it is proposed to convey them, first, after leaving the mercury boiler through a heater which raises the returning liquid almost to the boiling point; second, through a superheater which superheats the steam delivered by the condensing boiler; and third, through an economizer which heats the feed water for the condensing boiler and so reduces the gases to the lowest practicable flue temperature.

"By careful study and experimental development means have been devised for reducing the amount of mercury used, for effectively preventing its loss or dissipation, and for immediately detecting any failure in such prevention."

Mr. Emmet then goes on to discuss the disadvantages and the advantages of mercury for a heat engine.

"The disadvantages of mercury for such a process are: First, that it is very expensive, its cost being about 60 cents per pound. Second, that it is poisonous and is capable of pervading the atmosphere in a very finely divided state in the neighborhood of places where the vapor can escape. Third, there are certain difficulties in confining both the vapor and the liquid, although these, with proper methods, are not serious.

"Mercury's advantages as a thermodynamic fluid for the purpose desired are many. First, its boiling points at desired pressures are convenient. Second, its high specific gravity makes possible the use of gravity feed, sealing of valve stems, etc., and centrifugal sealing of turbine packings. Third, it is completely neutral, at the temperatures used, to air, water, iron, and such organic substances as it may come in contact with. Fourth, it carries nothing in solution which can adhere to or affect heating surfaces, consequently the interior of boiler is always perfectly clean. Fifth, its vapor density is so high that it gives a very low spouting velocity, and consequently a very simple type of turbine can be used. Sixth, it does not wet the surface of turbine blades and consequently gives apparently no erosion. Seventh, its volume at convenient condensing temperatures is such that it can be used in turbines without excessive bucket heights. One of the greatest limits of design in steam turbines is

the large area required for the efficient discharge of the low-pressure steam. With mercury vapor this difficulty does not exist. Eighth, delivering its heat at the temperature and in the manner which it does, the condensing boiler in which this heat is used to make steam is very small and simple as compared with a steam boiler. Steam boilers transmit an average of about 6 watts per square inch with an average temperature difference of about 1,100 degrees F. A surface condenser transmits 18 watts per square inch with 20 degrees F. temperature difference. The mercury boiler is about equivalent in dimensions to a surface condenser, and since there is no high temperature involved, there will be no possibility of scaling or burning. High temperature, unequal distribution of heat, and the necessity for large heating surface constitute the principal difficulties of boiler construction. All of these are overcome in this method of making steam."

As regards the economy to be gained by his process, Mr. Emmet remarks:

"Before entering into the details of experiments or of the methods by which it is hoped to accomplish these results, it may be well to state the degrees of economy which should be accomplished if this development succeeds. Assuming heat deliveries to surfaces exposed equal to those in steam boilers under equivalent conditions of temperature difference, gas velocity and radiation, and assuming a turbine efficiency equal to that of steam under equivalent velocity conditions, the calculation shows that in an efficient modern power station the same amount of steam can be delivered to the turbines at the same superheat, thus giving the same turbine output, and that in addition about 66 per cent. of the power so delivered can be delivered by mercury turbines, the fuel required being only about 15 per cent. greater than that which would be used with the steam alone. Thus the gain in capacity of an existing station would be approximately 66 per cent. and the gain of output per pound of fuel would be about 44 per cent. This calculation is based upon a mercury vapor pressure 10 pounds above the atmosphere and a vacuum of 28.5 inches at the steam turbine outlet.

"About 10 pounds of mercury would be evaporated for each pound of steam produced, the steam pressure being about 175 pounds gage, superheat 150 degrees F., and the final temperature after gas leaves economizer being about 300 degrees F. The vacuum in both steam and mercury turbines can be maintained by the same air pump, means being employed to separate all mercury vapor from the air in a suitable cooler.

"Experimental data indicate that not more than $10 worth of liquid mercury per kilowatt output of mercury turbine will be required for such a process, and it is probable that with suitable arrangements this amount can be considerably reduced. The general application of such a process would require immense quantities of mercury, but inquiry has indicated that the sources of supply are such that the largest conceivable demand for such a purpose would not permanently increase the price."

Mr. Emmet then proceeds to describe his mercury boiler:

"With a view to developing a design for a mercury boiler which would produce the vapor with the practicable methods of firing without destructive temperatures in the steel and with a small total amount of mercury in use, it has been necessary to do much experimenting to determine the behavior of mercury under boiler conditions. The construction of the boiler as finally developed is shown by Fig. 2, and the experimental unit used to determine its characteristics is shown by Fig. 3.

"This boiler is made up of a number of heating units, each consisting of an upper and a lower header which are connected together by curved flattened tubes. The flattening is to reduce the space which must be filled with liquid mercury without diminishing the surface. The curvature is to prevent mechanical strains through unequal expansion caused by irregular

heating. These flattened tubes are connected into the headers by acetylene-welded joints. The tubes are first welded from the inside into channel-shaped pieces; these channels with the set of tubes connecting them are then annealed so as to release all strains incident to the welding. After annealing, they are tested with high-pressure air, suitable clamps being used to confine the air in the channels. These channel pieces are then welded to steel headers so that the whole unit becomes perfectly tight and capable of standing a high pressure. The headers of these units terminate in taper nozzles, which fit into taper holes in the bus header at the bottom and into a vapor chest at the top. A curved liquid duct connects the vapor chest to the bottom header at the hot end so that the heating units which are exposed to the greatest heat receive the most direct supply of liquid. In these hot units a larger internal space will be allowed than in the units which occupy the cold part of the boiler, so that the colder part will not carry an unnecessary amount of liquid.

"The arrangements of the turbine have been improved as the result of experience. The first turbine arranged was made from an old experimental steam turbine, and had many joints which were difficult to keep vacuum-tight. The new experimental turbine has only one joint, arranged in a manner which has been experimented with and which will avoid leakage.

"The condensing boiler used in the experiment now in preparation is made from a standard high-pressure feed heater having a water space at the top and bottom connected by tubes in the manner customarily used in such devices. This boiler has apparently worked satisfactorily and produced steam from mercury vapor in the manner expected. It is not, however, considered a suitable design for the purpose, since the temperature differences impose a strain on the expanded tube sheets. It is thought that tubes attached at one end with concentric circulation after the manner of the Nicholaus boiler will afford the most satisfactory method for such condensers. Since no violent temperature differences will exist, it is believed that these condensing boilers can be made practically free from deterioration and entirely free from leakage."—"Scientific American."

CRACKED AND SEIZED PISTONS ON DIESEL ENGINES.

By Geo. E. Windeler.

(Read before the Diesel Engine Users' Association.)

In approaching the subject which we have before us today I have in mind that there has been a very considerable abount of research work carried out in different parts of the world in connection with the "growth" of cast iron and the difficulties with cast iron when subjected alternately to high and low temperatures, and therefore any remarks that I make on the subject are entirely based on the investigations which we have carried out at the works of the firm with whom I am associated.

Naturally there are many points in connection with the investigations which I am not at liberty to disclose, but I will endeavor to place before you the procedure that has been adopted and the results that have been obtained step by step, coupled with the modifications that have been made in design to meet the decisions that have been come to at the different stages of the investigations.

I am exhibiting a number of diagrams illustrating the different stages in the design of pistons we have used on various sizes of engines, and also a diagram, Fig. 6, showing the general arrangement of the combustion space, with the valves and piston in position, to illustrate my remarks in regard to the transmission of heat through water spaces.

In dealing with the internal-combustion engine as a heat motor, the points of difference between it and the steam engine are considerable. In the steam engine, to obtain the most economical results, everything possible is done to keep the temperatures of the cylinder liner, piston and ports for the incoming steam, and all surrounding spaces, as near as possible to the temperature of the live steam. To obtain the most efficient results steam jacketing has been resorted to, latterly superheated steam, and the latest innovation has been the adoption of the Uniflow engine, which admits steam by a set of ports which are placed at one end of the cylinder, and allows the exhaust steam to pass away through another set of ports situated either at the other end, or at the middle of the cylinder, according to the type of engine.

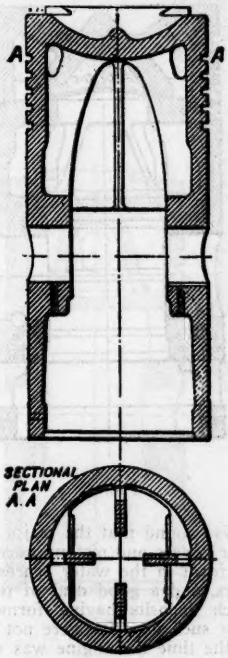


FIG. 1.

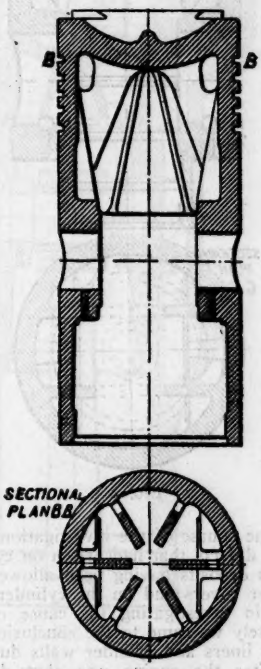


FIG. 2.

In the internal-combustion engine (in this particular instance I will deal specially with the Diesel engine) everything possible is done to keep down the temperature of the cylinder liner, cylinder cover or breech end, exhaust valves and exhaust passages which are in contact with the fuel or gases. In some types the pistons are water or oil cooled. In a well-designed Diesel engine 40 per cent. of the heat units admitted to the combustion space is absorbed in useful work. Of the remainder, 25 per cent. passes to the exhaust and 35 per cent. passes away to the circulating water and is lost in radiation, so that almost as much heat has to be absorbed by the cooling water as is developed in useful work; therefore

special attention has to be paid to water-cooling arrangements to ensure that the circulation is thorough and that no air or steam pocketing is likely to occur, and special attention should be paid to the arrangements to prevent short circuiting in the water circulation, otherwise certain parts are liable to become overheated locally.

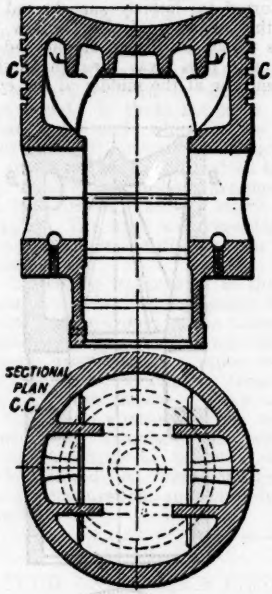


FIG. 3.

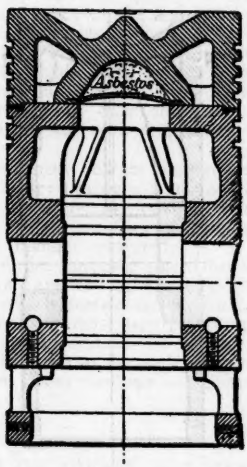


FIG. 4.

In the course of the investigations it was found that the major portion of the defects that had arisen on cylinder covers and pistons were due to serious deposits having been allowed to form in the water spaces of the cylinder covers and on the cylinder liners, and a good deal of time was spent in investigating the cause of such deposits having formed, and ultimately we came to the conclusion that such deposits were not formed on the liners and cylinder walls during the time the engine was working but after the engine was shut down. Naturally, the piston, cylinder cover, valves and such parts as are in contact with the combustion space must have a large number of heat units stored in them, and when the engine is shut down these heat units are absorbed by the water which remains in the jacket, the quantity of which is comparatively small, and a very considerable rise in temperature takes place; in fact, sufficiently high in the majority of cases to throw down the salts which were held in solution in the water. We were so sure that the theory was correct (which, as far as we knew, was quite a new interpretation of the difficulty) that we wrote to the various users of our engines suggesting to them, where the circulating water was known to be of a considerable hardness, that they should run water through the water spaces for some time after the engine was shut down—with the most happy results. This

information, naturally, became public, and most Diesel engine users have now adopted this system to their advantage.

I have personally inspected a cylinder cover which contained a water space about 6 inches deep and found a deposit of as much as 5 inches thick in the water space. Naturally, the cover had cracked. The aforesaid suggestion was adopted in this particular station, and the results have been very satisfactory indeed.

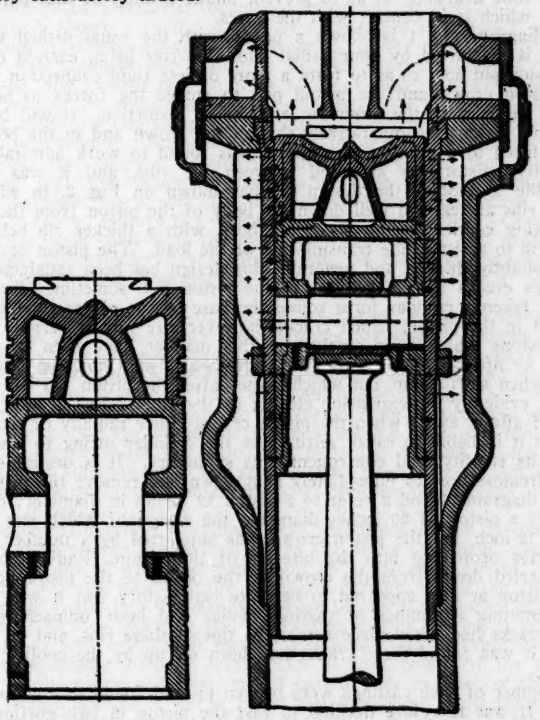


FIG. 5. FIG. 6.

In an internal-combustion engine without a water-cooled piston the heat units that have been absorbed by the piston crown must, out of necessity, be dispersed from the crown down the body of the piston, and passed away through the liner to the water space by the contact that the piston forms with the liner. It is therefore necessary to study carefully the design of the piston head to obtain the best results. At the same time the piston must be designed in such a way that the load that is applied to the crown shall be transmitted to the crosshead pin which attaches to the connecting-rod, without causing any distortion to the piston, which has to maintain its roundness to enable it to work without trouble in an accurately-bored cylinder.

In the small internal-combustion engine such as is used on automobiles and air craft, there is quite a difference of opinion as to whether cast iron

or oil-tempered steel is the most suitable material to use for pistons. One would almost imagine that the oil-tempered steel piston would be the most suitable for such machines, where high power is developed in comparatively small cylinders, and at a high rate of revolution; but for large engines such as we have under discussion it is necessary to have a fairly heavy section of material to enable the heat units to pass away in the time available, so as to prevent undue heating of that part of the piston which is in contact with the gases.

In diagram No. 1 is shown a piston with the usual dished top, and which is supported by four radial ribs, two ribs being carried down to the piston-pin boss so as to form a more or less rigid connection between the piston crown and the piston pin, to enable the forces to be transmitted direct with the minimum amount of distortion. It will be noted that this piston is comparatively thin in the crown and in the body, and when fitted to a number of engines, was found to work admirably; but ultimately distortions appeared between the ribs, and it was deemed advisable to modify the design to that shown on Fig. 2, in which six radial ribs are carried well down the body of the piston from the crown, two being carried to the piston-pin boss, with a thicker rib behind the main rib to assist in the transmission of the load. The piston crown was made slightly thicker, and generally this design has been satisfactory, but at times cracks have developed in the piston top, sometimes the cracks having taken a circular form round the base of the center cone which is formed in the piston. Such cracks, however, are not of serious import, and pistons which have cracked in this manner have been in use for twelve or fifteen months without any trouble, a slight blowing past taking place when starting up, but which ceases after the piston top has become heated, evidently the expansion closing up the crack. But a more serious state of affairs exists when the piston cracks either radially or diametrically, as it is liable to cause seizures in the cylinder owing to the piston losing its rigidity, and consequently its symmetry. It is desirable under such circumstances to immediately shut down and remove the piston.

The diagrams 1 and 2 refer to a piston 12 inches in diameter; diagram 3 shows a piston of 20 inches diameter, the design of which was similar to the 12-inch, but the piston crown was supported by a number of circular ribs projecting into the interior of the piston. Radial ribs were also carried down from the crown of the piston to the piston-pin boss. This piston at first appeared to be quite satisfactory, but it was noticed on examining a number of castings which had been unmachined that slight cracks had taken place across the tips of these ribs, and on examination it was found these cracks had been set up by the cooling of the casting.

A number of such castings were broken up and found to contain many flaws. It was therefore decided to cast the piston in two portions, and diagram 4 illustrates the type of piston which is now generally adopted by the firm. The construction of the upper portion of the piston is secured to the main body of the piston by six or eight square-necked studs; the object of the square-necked stud, which fits into a square hole in the body of the piston, is to ensure that the stud itself will not come out or get slack when the engine is at work.

The design of this piston top is somewhat novel, insomuch that there are no ribs embodied in the design, the support to the crown of the piston top being obtained by throwing out a conical cylindrical chamber which also has the advantage that it forms another lane by which heat units can reach the body of the piston for transmission to the water spaces. It also permits of uniform expansion. The upper portion of the piston is carefully bedded on to the lower portion, and care has been taken to have sufficient contact area to allow for rapid heat transmission. The internal cone thus formed in the head is filled with asbestos to prevent the heat being thrown down from the crown of the piston on to the connecting-

rod bearing. This design has several advantages, one being that different quantities of material may be used for the upper portion of the piston and the lower portion. The other is, that should any cracks develop, it is a comparatively simple and inexpensive matter to replace the top. As will be readily understood, the lower portion, which acts as a crosshead, must necessarily be of a quality of iron which is hard and which will attain a high polish when running, and not wear readily; the upper portion should be of a material capable of resisting heat stresses.

Diagram 5 shows a similar design as adopted on the 12-inch pistons. When these modifications were carried out, a number of experiments and analyses were made by our laboratory with the different qualities of material used, and careful records were taken of such, and when any defects developed we were able to trace the particular quality of material that was used. By this comparative method we were able to arrive at a more or less definite conclusion as regards the quality of material which best suited the purpose. Ultimate experiments proved that cast iron containing high percentages of phosphorus were most unreliable, and further investigations proved that the eliminations of phosphorus would, to a large extent, remove the difficulty of cracks developing. Great care is taken by us in controlling the mixtures that are used, and each batch of pistons and cylinder covers, liners, etc., is carefully analyzed, and records taken by our laboratory so as to ensure consistency of the material as desired.

Reverting to the question of seizures of pistons, we have formed the opinion that almost invariably these seizures are due to heating of the piston pin and its bearing, and from our investigations we have found that such seizures take place almost immediately after starting up. The opinion we have formed is that, when an engine has been set to work and shut down, the heat stored in the piston body is thrown down and tends to evaporate the oil in the top end bearing, with the result that when the engine starts up again, this particular bearing is not amply supplied with lubricating oil, and seizures take place. Again, running the circulating water through the engine after shutting down tends to minimize this difficulty.

In the enclosed type of engine, where forced lubrication is used, this difficulty is to a large extent removed by the fitting of a hand-lubricating pump, by means of which lubricating oil under pressure can be pumped to all the bearings, including the piston-pin bearing, whilst the engine is being barred round into its starting position before being started up.

As proof of the contention that the heating of this bearing is generally the cause of such seizures, it may be mentioned that the abrasions generally show seizure to have taken place at four points of the circumference of the piston and liner, and if careful note is taken of the position of these abrasions, it will be found that they occur at the point where the piston-pin bosses join on to the thinner section of the body of the piston. At this point there is a comparatively sudden reduction in the section of material, allowing one portion of the piston to be extremely rigid and the other portion more or less flexible; when seizures take place the piston pin becomes overheated, and by reason of its friction fit in the piston body, plus its greater coefficient of expansion, causes an extension to take place, which forces the piston out of shape, flattens the crosshead portion of the piston body, and causes distortion to occur at the four points referred to. If the engine is not shut down quickly, other seizures are liable to occur, but the main seizures will almost invariably be found to occur at these four points.

When piston seizures do occur it is desirable that the connecting-rod bolts should be carefully examined, as extension of the length of the bolt is likely to take place, and if examination is not made, ultimately fractures of the bolts are likely to occur, with most disastrous results.—"Page's Engineering Weekly."

CONTROL AND PROTECTION OF ELECTRIC SYSTEMS.*

By Charles P. Steinmetz.†

When the first commercial electric circuit issued from a station the problem of control and of protection arose. It was a simple problem at first—an ammeter and voltmeter to measure current and voltage; a knife-blade switch to send the current into the desired path or withdraw it; the fuse to open the circuit in emergencies, and if the wires became crossed and the fuse and switch failed, the generator and engines stopped, and not much harm was done. With the extension of the circuits into the suburbs some lightning troubles were felt, which led to the introduction of lightning arresters.

Since those days, less than a generation ago, enormous changes have taken place, and the electric systems have increased in size, in voltage and in extension. Where 100-H.P. machines were large once, now turbo-alternators of over 40,000-H.P. are in commercial operation. The steam engine has made room for the steam turbine, and the steam turbine does not stop when the wires are crossed and a short-circuit occurs; the momentum of the turbine discs, revolving at velocities of 300 to 400 miles per hour, can supply ample energy for the destruction of any part of the system. Attempts to open such circuits by the knife-blade switch of old would lead to the destruction of the switch, and probably its operator.

Instead of small machines operating separately on independent circuits, huge generators now feed in parallel into the system of busbars, on which is concentrated all the power of the station or the group of stations tied together. Numerous stations and systems of interconnected stations of 100,000 to a quarter-million horsepower and over are in operation, and the half-million horsepower mark has been reached.

Anywhere on the busbars of the station or in the feeders near the station there is available, destructively in case of an accident, as a short-circuit, not only the entire power of the station, but the far greater power which the station generators can give momentarily. Short-circuit currents of forty to fifty times normal full-load current may momentarily flow from some turbo-alternators, representing ten and more times full-load power. Such a station, or group of closely interconnected stations, of half a million horsepower full-load capacity, may momentarily send into a short circuit at the busbars over five million horsepower. This is the power of Niagara, which is estimated variously at from 5,000,000 to 15,000,000 H.P. It is obvious that no switch or circuit breaker can be built to safely relieve such power.

With half a million horsepower station capacity, a momentary overload capacity ten times as high, assuming that we could build a circuit breaker to open this short-circuit power as quickly as in three to four cycles, or one-eighth second, would require dissipating in the circuit breaker the energy of over 200,000,000 foot-pounds—the destructive energy of 1,000 tons dropping from a height of 100 feet, that of a projectile weighing 2,000 pounds leaving the cannon at a velocity of 2,500 feet per second, or the destructive energy of two heavy railway trains, going at sixty miles per hour, and meeting headon.

Equally great has been the increase of voltage. Where once 2,000 volts was high, in circuits of a few miles in length, now circuits of over two hundreds miles are in operation at 100,000 to 150,000 volts. Current at such voltages jumps toward an object over a foot distant, and will maintain arcs of practically unlimited distance; that is, with 100,000 volts and almost unlimited power back of it, an arc can extend for several hun-

* From a paper presented at a joint meeting of the Philadelphia Section, A. I. E. E., and the Franklin Institute and printed in the July "Journal" of the Institute.

† Chief consulting engineer, General Electric Co.

dred feet. Thus no simple switch will open a circuit at such voltages under power.

Lightning protection also has become a far larger problem than in the small circuits of old. But far greater than the energy of any lightning stroke is the energy stored as magnetic field surrounding the conductors and as dielectric field radiating from the conductors of these big transmission systems, and, if this internal energy of the system is set surging, its effects are far more destructive than those of lightning. The effects may not be merely momentary, as those of lightning, but continual, as machine energy keeps replacing the stored internal energy which causes the destructive surge. The foremost problem of control of electric systems thus is that of controlling enormous powers; the foremost problem of protection is that against self-destruction by its own power.

Current and voltage have grown beyond the values for which instruments can be built, and current transformers and voltmeter transformers are interposed between the circuit and the instruments measuring it. With the general introduction of parallel operation, power-factor indicators are required to insure the division of load without excessive waste currents, and frequency indicators and synchronizing devices to safely connect machines into the system.

With hundreds of feeders radiating from the generating station the office of the load dispatcher has become essential, and the necessity of keeping exact records of all operations and of all accidents and incidents is of the greatest importance. Automatic recording devices thus have been developed, as the multi-recorder, to record within fractional seconds all important events—opening and closing of switches, starting and stopping of generators, surges, lightning disturbances, etc. Such automatic devices afford a valuable check on the operating staff, but more important still is their record in emergencies. Where a number of things happen almost at once and the attention of the operator is distracted from accurate observation by the necessity of action, the record thus could be made only afterwards from memory. It is just in such abnormal conditions where the most complete and accurate record is of greatest importance, to enable the engineers to determine with certainty what happened and why it happened, so as to take steps to guard against its recurrence.

Oil circuit-breakers have been developed, which can safely and without disturbance close and open feeder circuits of over 10,000 H.P. and generator circuits of 40,000 H.P. In these the circuit is opened under oil so that at the instant of opening the current is extinguished at the end of a half-wave by the rapid expansion and chilling of the oil vapor produced by the opening arc; this at first is under high compression, due to the momentum of the oil which has to be set in motion.

POWER-LIMITING REACTANCES.

The possibility of self-destruction by the power let loose under short circuit was solved by the development of the power-limiting reactances. In the generator leads, between generators and busbars, are inserted reactances capable of withstanding enormous overloads, but of a size sufficiently small not to interfere with the normal flow of power at full load or any overload that the generator may be called upon to carry. They are large enough, however, to materially limit the generator current and power on short circuit. Usually the generator reactances limit the momentary short-circuit current to about ten to twelve times full-load current; that is, the momentary short-circuit power to about two and one-half times full-load power. This solved the problem for medium-sized stations.

However, even with generator reactances, with the increasing size of station, the power that may be let loose under short circuit becomes large beyond control, and busbar reactances were next introduced. By such reactances in the busbars and in the tie feeders between the stations, the

system is divided into sections of about 60,000 H.P. each. A short circuit then can seriously involve one busbar section only.

With hundreds of feeders radiating from the busbars, the probability of a short circuit in the feeders is far greater than in the busbars, and a material advantage, therefore, is given by feeder reactances.

By the development of generator reactances, busbar reactances, and feeder reactance, the problem of the power control of large systems for protection against self-destruction by short circuit has been solved, and unlimited extension of systems without any increase of danger has been made possible; and experience has shown that after the introduction of such power-limiting reactances dead short circuits have occurred at the busbars of very large systems without even interfering with the operation of most of the synchronous apparatus on the system.

GROUNDS AND SHORT CIRCUITS BETWEEN PHASES.

The two main sources of trouble in lines and cables are grounds and short circuits between phases. In transmission lines a ground on one phase is the most frequent trouble, and short circuits are rare except in lines in which the design is faulty or reliability has been sacrificed to cheapness. A short circuit is far more serious than a ground, as in the former the current is limited only by the generator capacity, while with a ground the current has no return unless the neutral is grounded, and then over the resistance of the neutral. In a well-designed transmission line a short circuit usually occurs only as the result of two simultaneous grounds. A ground on one conductor, however, raises the voltage to ground of the other two phases, from the Y voltage to the delta voltage of the system, and thereby increases the strain on the insulation of the other two phases. It thus introduces the danger of a second ground, causing a short circuit, or requires higher insulation.

This has led to two methods of operation of transmission systems. In the first, the neutral of the transformers is grounded, frequently through a resistance, where the resistance of the ground is not high enough to limit the current. Then a ground on one phase is a partial short circuit to the neutral, causing a large current to flow, and thereby opening the circuit breakers before the ground has developed into a short circuit. However, this method, the grounded Y system, means a shutdown at every ground, every flashover of an insulator by lightning, etc. In the second method the neutral is not grounded, but the insulation of the circuit is good enough to safely stand the increased strain put on it by a ground on one phase, and by means of an arcing ground suppressor, etc., care is taken not to continue the arcing ground, leading to high-frequency disturbances, but convert it into a metallic ground. In this case the "isolated delta" system can be maintained in service, even if one phase grounds, until arrangements are made to take care of the load or the fault is found and remedied. However, the cost of line construction is higher, because of the better insulation required. The relation between grounded Y and isolated delta is one of cheapness versus reliability and continuity of operation.

PROTECTING UNDERGROUND CABLES.

Different are the conditions in underground-cable systems. In a cable the three conductors are so close together that a ground on one conductor quickly reaches the others and becomes a short circuit. A grounded cable, therefore, cannot be kept in service, but has to be cut out promptly. In these systems it is customary to ground the neutral through a resistance sufficiently low, in case of a ground on one conductor of a cable, to allow enough current to flow to open the circuit breaker and cut off the cable, but not sufficient to give a severe shock to the system. Or, where grounding of the neutral is considered undesirable, an arrangement of relays is made to give the same effect. With underground cables such cutting off of a disabled feeder does not interfere with the continuity of

service, as a number of feeder cables are always used in multiple for every important substation.

However, the problem of cutting off a disabled feeder by the operation of the circuit breaker, owing to the large current taken by the grounded feeder, is not so simple. Therefore, so-called "inverse time-limit" circuit breakers are generally used; that is, circuit breakers in which the time limit of their operation decreases with increasing overload. Such circuit breakers would first cut off the cable carrying the greatest excess current —that is, the faulty cable—and then those of less excess current; but, as the excess current stops with the cutting off of the faulty cable at both ends, other cables should not be interfered with. However, the inverse time-limit circuit breaker necessarily must be practically instantaneous under short circuit, and therefore, while the time limit discriminates between 100 per cent. or 200 per cent. or 300 per cent. overload, it cannot discriminate between short circuits of different magnitude.

Thus devices become necessary for selecting a disabled feeder and cutting it out without cutting off its parallel feeders or the tie feeders to the substation served by the faulty feeder, regardless of what excess currents these may carry. This is a problem that has not yet been completely solved.

In general, in high-power systems of high standard of reliability the radial system of substation supply is used; that is, each substation is fed by a separate set of cables, and the substations are not interconnected into a network by a system of tie feeders. This radial system, however, is less economical in feeder copper than the interconnected network, since the radial system requires for each substation a feeder capacity equal to the maximum power demand of the individual substation, while in the network, by cross-feeding between the substations, the feeder capacity is reduced to that required by the average maximum demand of the substations. Because of the economic disadvantage of the radial system an effective selective feeder relay that could be relied upon to pick out the faulty feeder and no other would offer material advantages.

Such a selective device is afforded by the use of pilot cables. Each cable or feeder is duplicated by a smaller low-voltage three-phase cable, which joins the secondaries of current transformers connected into the two ends of the main cable. If the main cable is undamaged the same current comes out of it as flows into it, and the connections to the pilot cable are such that in this case the secondary currents would be in opposition; that is, neutralize each other. If, however, the main cable grounds, current flows into it from both sides, the secondary currents in the pilot cable then add, and the current flowing in the pilot cable operates the relay which opens the circuit breaker. This arrangement is very perfect in operation, and is capable of cutting out the damaged cable without interfering with any other, but it has the disadvantage of doubling the number of cables required in the system. While the pilot cables are small and of low voltage, they occupy room in the underground ducts; hence, this method of control is little used in this country.

Another method is that of the split-conductor cable. Every cable conductor is made of two parts, of which the one surrounds the other concentrically, with some insulation between them. Normally there is no potential difference between the inner and the outer half of the conductor, as they are connected with each other at the ends of the cable. If, however, a ground occurs on the cable, this ground can at first reach only the outer half of the conductor, and a potential difference and current appears between the inner and the outer half of the conductor and operates the circuit breakers through a relay connected between the halves of the conductor, at either end of the cable. This method also works very satisfactorily, but has the same economic disadvantage, though to a lesser degree than the method of pilot cables, in that the split-conductor cable is materially larger and more expensive.

The usual method of taking care of the problem, at least in most cases, is by the so-called reverse-power relay, also wrongly called "reverse-current relay." Such a reverse-power relay operates perfectly so long as there is any voltage for the reverse current to act upon. If, however, a short circuit occurs at or close to the substation, the voltage vanishes, and with it the reverse-power relay loses its pull. To guard against this the installation of reactances is recommended between cables and substations to give a sufficient voltage drop to operate the relay. However, this is an additional complication.

The reverse-power relay is not adapted to guard the feeders between stations, as in these the current reverses in direction with the change of the distribution of load between the substations. Thus the reverse-power relay does not make the operation of interconnected networks of substations possible, but in the radial system of operation it is the only device which is generally available economically, and it is very satisfactory, with the exception that it cannot operate where there is no voltage left.

LIGHTNING INTERFERENCE.

Interference by lightning with high-potential transmission lines, has rather decreased with increasing line voltage. In 100,000-volt lines the insulators are tested for one minute at 200,000 to 250,000 volts and stand momentarily for the very short time of lightning, over half a million volts. Thus it is rare that lightning flashes over or punctures the suspension insulators of our very high-voltage transmission systems. A flashover, with the grounded Y system, shuts down the circuit, often without any damage, while with the isolated delta system it may not even shut down the circuit, but is taken care of by the protective device against flashovers—the arcing ground suppressor in the station. Most lightning voltages incapable of destroying the line insulation run along the line until their energy is dissipated or they reach a station, and there they often do serious damage. The most important problem of lightning protection thus has become the rapid damping out of line disturbances caused by lightning, so as to make them harmless before they reach the station. The most effective method has been the overhead ground wire. By its screenings effect it lowers the voltage which lightning can induce in the line, but far more important is its powerful damping effect on the line disturbance—the traveling wave caused by lightning which runs toward the station.

In considering the protection of modern electrical systems it must be realized that the various sources and kinds of interference or danger require correspondingly different protective devices. It would be just as unreasonable to expect a standard type of "lightning arrester" to protect an electric system against all possible troubles as it would be to call for a single-standard "safety device" which would protect a railway train against all possible dangers, from a broken rail or a washout to a collision or a boiler explosion.—"Power."

FIRST AMERICAN REVOLVING FLOATING CRANE.*

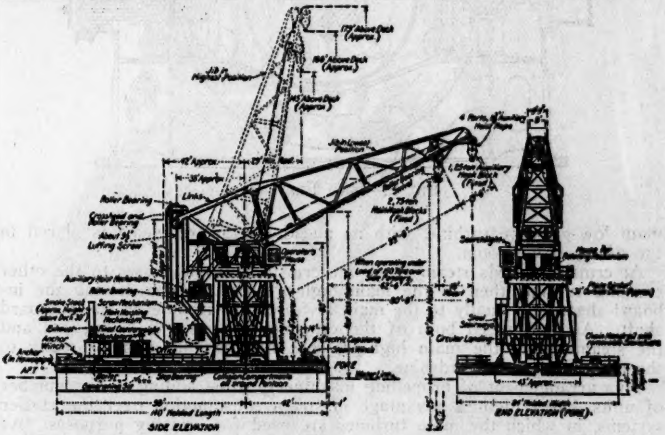
HIGH-CAPACITY LIFTING APPARATUS FOR NAVY YARD.

A. F. Case—"Engineering News."

For the Norfolk Navy Yard a 150-ton capacity floating crane, illustrated herewith, is to be built by the Wellman-Seaver-Morgan Company, the first of its kind constructed in this country. It will weigh when built 2,500 tons and cost $350,940.

* cf. "The Engineering Magazine," July, 1915; p. 584.

It consists of a steel tower on a steel pontoon with a pivot frame carrying the operating jib revolving in the tower. The crane will lift 150 tons at a maximum reach of 62½ feet over sides or one end. This load will be carried on two separate hooks some ways back from the end of the jib, and an auxiliary hook on a trolley capable of operation from the end of the jib will be capable of hoisting from a point 25 feet below the water to 130 feet above the water at 62½ feet beyond the fender. The jib can be luffed under load from maximum reach to a minimum of 29 feet.



ELEVATIONS SHOWING ESSENTIAL FEATURES OF THE CRANE.

The crane will be electrically operated, all the machinery being carried in a machinery house on the rotating structure. Power is obtained from a steam-operated generating set on the pontoon. The pontoon will be 85 feet wide, 140 feet long and 15 feet deep.

The motors are all of one size, provided with magnetic-switch control, the master controllers being situated in the operator's cab. The electric current will be supplied at 250 volts by a non-condensing compound engine driving a 150-kilowatt direct-current generator.

REDUCTION GEARS ON THE *PENNSYLVANIA*.

CRUISING TURBINES FITTED WITH WESTINGHOUSE HYDRAULIC FLOATING-FRAME REDUCING GEARS, DESIGNED TO TRANSMIT 1,600 HORSEPOWER.

The general features of the machinery for the United States battleship *Pennsylvania* have been briefly discussed in the engineering press. Now that the cruising gears have been built, some additional information regarding their construction will be of more than passing interest.

The *Pennsylvania* has four shafts and propellers. Each inboard shaft is driven by a high-pressure turbine placed in the forward engine room and has an independent backing turbine located in an engine room immediately aft of the forward one. Each outboard shaft is connected to two cruising turbines, located in the forward engine room, and also to the

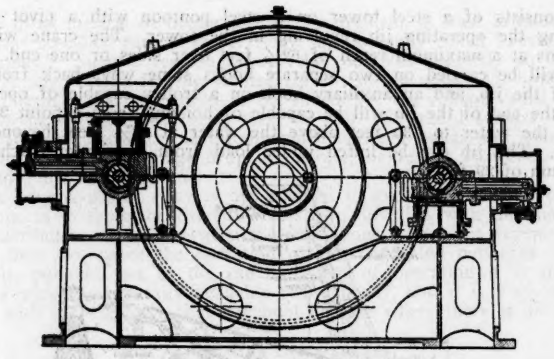


FIG. 2.—END ELEVATION.

main low-pressure turbine, with its ahead and astern elements placed in the after engine room.

At cruising speeds steam from one cruising turbine passes to the other cruising turbine, then to the main high-pressure turbine driving the inboard shaft, and finally to the main low-pressure turbine on the outboard shaft. At high speed both of the cruising turbines are disengaged and the steam enters the main high-pressure turbine and passes directly to the main low-pressure turbine.

This arrangement of propelling machinery, while adding to the number of units, has a distinct advantage in steam consumption over the earlier systems, in which the main turbines are used for cruising purposes. As about 90 per cent. of the total voyages of a battleship are made at cruising speed, the importance of obtaining the highest possible economy at this speed is apparent.

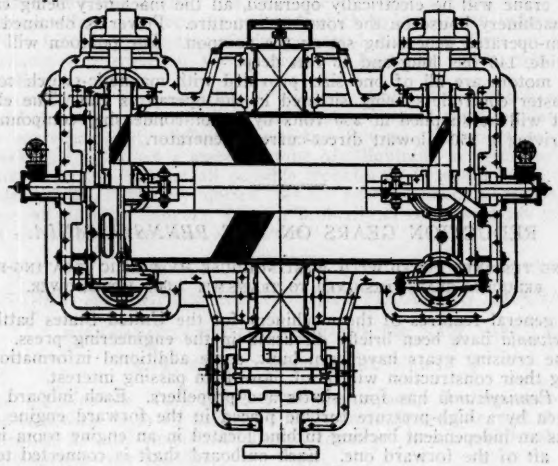


FIG. 3.—PLAN.

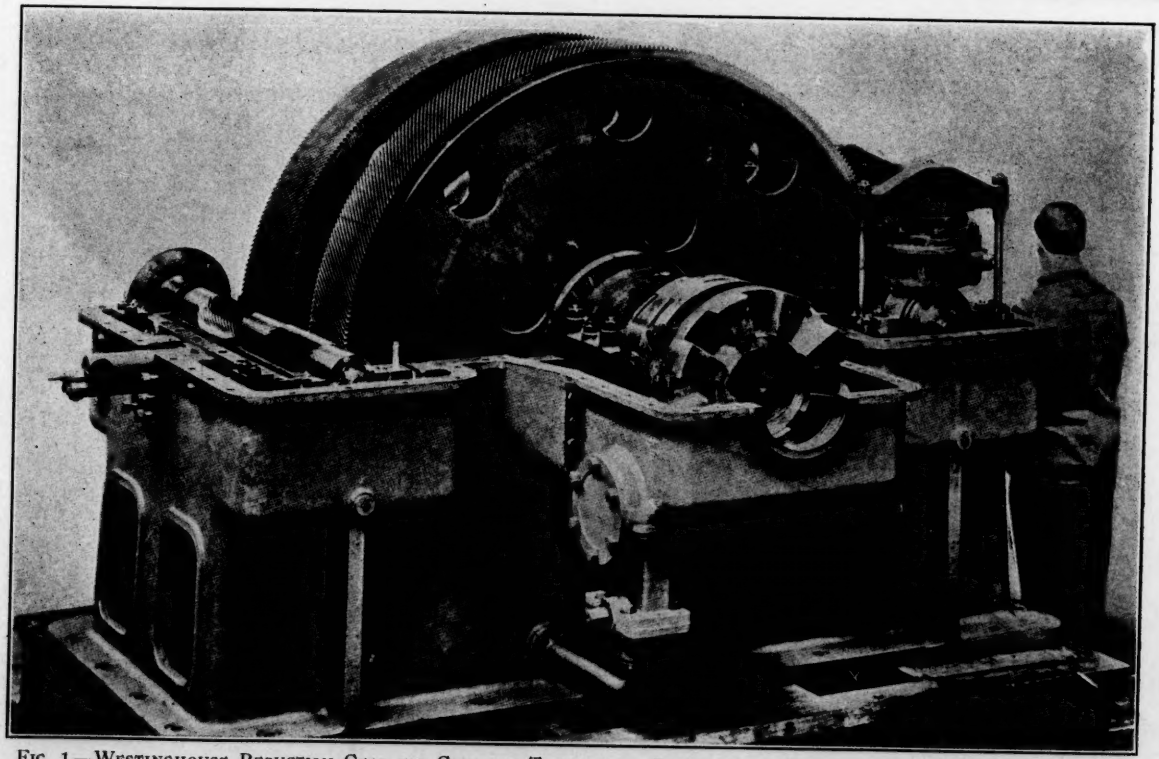


FIG. 1.—WESTINGHOUSE REDUCTION GEAR FOR CRUISING TURBINES OF BATTLESHIP "PENNSYLVANIA." SPEED REDUCTION, 1,800 TO 120; HORSEPOWER TRANSMITTED, 1,600; WEIGHT, 23,000 POUNDS.

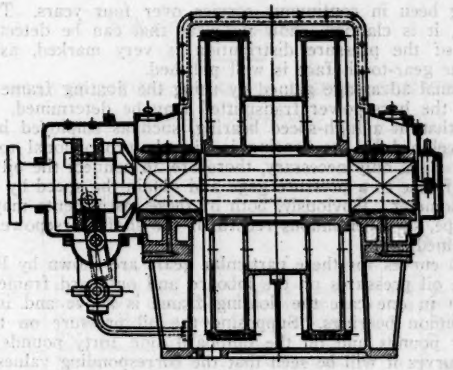


FIG. 4.—SIDE ELEVATION.

In order to get this better economy the two high-speed cruising turbines are connected to the outboard propeller through the medium of a two-pinion Westinghouse hydraulic floating-frame reduction gear. The details of these gears are clearly shown by the end elevation, Fig. 2; the plan view, Fig. 3, and the side elevation, Fig. 4. The clutch coupling on the main gear shaft serves to disconnect the cruising turbines when the vessel is traveling at full speed.

The general construction is the same as used on all high-speed, high-power gears built by the Westinghouse Company, the distinctive feature of these gears being the use of the floating frame, which insures uniform tooth pressures under all load conditions. The practical value of the floating frame has been thoroughly demonstrated, some of the first gears

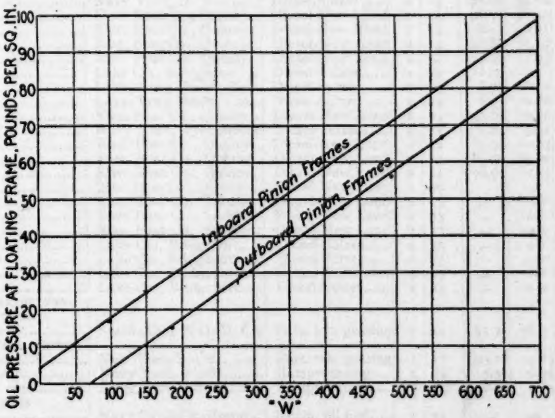


FIG. 5.—FLOATING FRAME CALIBRATION CURVES U. S. S. "PENNSYLVANIA" CRUISING REDUCTION GEARS. B.H.P. = W × R.P.M. OF GEAR WHEEL × 0.0118.

built having been in continuous service over four years. The teeth of these gears, it is claimed, show no wear that can be detected, and the uniformity of the pressure distribution is very marked, as the whole length of the gear-tooth face is well polished.

An additional advantage gained by using the floating frame is the ease with which the horsepower transmitted may be determined. Experience has shown that in a high-speed bearing, such as employed here, the oil pressure developed by the bearing is directly proportional to the power transmitted. It is only necessary, therefore, to connect the oil pipes from the floating frame to a pressure gage and obtain the speed by means of a suitable tachometer. Obviously, both of these instruments may be of the recording type, so a continuous record of the shaft horsepower developed may be obtained.

Calibration curves for these particular gears are shown by Fig. 5. The difference in oil pressures on the inboard and outboard frames is due to the fact that in one case the floating frame is above and in the other below the pinion bearings. Supposing the oil pressure on the inboard side is sixty pounds and on the outboard side forty pounds; from the calibration curves it will be seen that the corresponding values of W are 415 and 367, respectively. Multiplying the sum of these, or 782, by the revolutions per minute of gear wheel and by the constant 0.0118, the shaft horsepower is readily obtained.

The general construction of these gears and their size are clearly shown in Fig. 1. Each gear is designed to transmit sixteen hundred shaft horsepower, with a speed reduction from eighteen hundred to one hundred and twenty revolutions per minute. The weight of each gear exclusive of the clutch is twenty-three thousand pounds.—"International Marine Engineering."

NAVAL VESSELS.

UNITED STATES NAVAL VESSELS UNDER CONSTRUCTION.

DEGREE OF COMPLETION.

No.	Vessel.	Building yard.	Engines.	No. shafts.	Speed, knots.	Percentage machinery completed 1915.		Percentage of completion Aug. 1, 1915.	
						July 1	Aug. 1	Total.	On ship.
	BATTLESHIPS:								
36	*Nevada*	Fore River S. Co.	Curtis turbine	2	20.5	94.13	94.79	94.7	94.4
37	*Oklahoma*	New York S. Co.	Reciprocating	2	20.5	96.32	96.55	97.3	97.2
38	*Pennsylvania*	Newport News Co.	Cur. trb. grd. cr.	4	21	75.11	78.57	84.0	80.8
39	*Arizona*	Navy Yard, N. Y.	Pars. trb. grd. cr.	4	21	46.57	51.15	68.9	65.5
40	*California*	Navy Yard, N. Y.	Electric	4	21	...	...	...	...
41	*Mississippi*	Newport News Co.	Cur. trb. grd. cr.	4	21	4.61	7.96	25.7	9.9
42	*Idaho*	New York S. Co.	Pars. trb. grd. cr.	4	21	18.82	23.64	35.5	22.1
	DESTROYERS:								
53	*Winslow*	Wm. Cramp & Sons	Cramp trb. & rec.	2	29	96.92	97.95	97.6	97.6
55	*Cushing*	Fore River S. Co.	Curtis trb. grd. cr.	2	29	97.38	97.38	98.3	98.3
56	*Ericsson*	New York S. Co.	Pars. trb. & rec.	2	29	98.00	99.33	100.0	100.0
57	*Tucker*	Fore River S. Co.	Curtis trb. grd. cr.	2	29.5	66.82	79.36	79.3	76.7
58	*Conyngham*	Wm. Cramp & Sons	Pars. trb. grd. cr.	2	29.5	79.41	81.48	82.2	80.9
59	*Porter*	Wm. Cramp & Sons	Pars. trb. grd. cr.	2	29.5	77.18	78.99	76.8	75.4
61	*Jacob Jones*	New York S. Co.	Pars. trb. grd. cr.	2	29.5	84.08	88.12	83.7	83.7
62	*Wainwright*	New York S. Co.	Pars. trb. grd. cr.	2	29.5	84.00	87.93	83.5	83.5
63	.....	Fore River S. Co.	Curtis trb. grd. cr.	2	29.5	40.57	51.98	36.7	31.4
64	.....	Fore River S. Co.	Curtis trb. grd. cr.	2	29.5	40.93	44.50	34.2	28.1
65	.....	Bath Iron Works	Pars. trb. grd. cr.	2	30	26.21	31.58	32.7	27.3
66	.....	Bath Iron Works	Pars. trb. grd. cr.	2	30	26.21	30.07	31.1	25.5
67	.....	Wm. Cramps & Sons	Pars. trb. grd. cr.	2	29.5	22.70	24.71	15.4	7.1
68	.....	Navy Yard, Mare Isl'd	Pars. trb. grd. cr.	2	29.5	6.15	8.8	4.8	4.4
	FUEL SHIPS:								
13	*Kanawha*	Navy Yard, Mare Isl'd	Reciprocating	2	14	99.95	99.95	...	...
14	*Maumee*	Navy Yard, Mare Isl'd	Diesel	2	14	65.47	69.65	95.1	94.7
15	*Cuyama*	Navy Yard, Mare Isl'd	Reciprocating	2	14	...	...	...	...
	SUBMARINES:								
31	*G-3*	Navy Yard, N. Y.	Diesel-Sulzer	2	14	93.00	93.00	88.6	88.4
40	*L-1*	Elec. Boat Co., Quincy	Diesel-New Lond	2	14	98.41	98.41	98.4	98.4
41	*L-2*	Elec. Boat Co., Quincy	Diesel-New Lond	2	14	98.41	98.41	98.4	98.4
42	*L-3*	Elec. Boat Co., Quincy	Diesel-New Lond	2	14	96.89	96.89	93.3	93.3
43	*L-4*	Elec. Boat Co., Quincy	Diesel-New Lond	2	14	95.99	95.99	92.6	92.6
44	*L-5*	Lake Co., Bridgeport	Diesel-Sulzer	2	14	12.00	12.7	74.4	69.8
45	*L-6*	Lake, Long Beach, Cal.	Diesel-Sulzer	2	14	8.97	10.61	64.1	60.9
46	*L-7*	Lake, Long Beach, Cal.	Diesel-Sulzer	2	14	8.97	10.69	61.9	57.9
47	*M-1*	Elec. Boat Co., Quincy	Diesel-New Lond	2	14	91.66	92.79	83.6	81.1
48	*L-8*	Navy Yard, Portsmouth	Diesel-Sulzer	2	14	4.84	3.42	43.6	38.9
49	*L-9*	Elec. Boat Co., Quincy	Diesel-New Lond	2	14	89.92	89.63	76.6	72.2
50	*L-10*	Elec. Boat Co., Quincy	Diesel-New Lond	2	14	88.52	89.29	73.2	67.8
51	*L-11*	Elec. Boat Co., Quincy	Diesel-New Lond	2	14	78.95	87.05	67.8	61.2
52	*Schley*	Elec. Boat Co., Quincy	Diesel-New Lond	2	20	...	...	...	...
53	*N-1*	Elec. Boat Co., Seattle	Diesel-New Lond	2	13	...	10.6	11.2	...
54	*N-2*	Elec. Boat Co., Seattle	Diesel-New Lond	2	13	...	10.6	11.2	...
55	*N-3*	Elec. Boat Co., Seattle	Diesel-New Lond	2	13	...	10.6	11.2	...
56	*N-4*	Lake Co., Bridgeport	Diesel-Sulzer	2	13	...	4.0	29.7	27.1
57	*N-5*	Lake Co., Bridgeport	Diesel-Sulzer	2	13	...	4.0	29.1	26.8
58	*N-6*	Lake Co., Bridgeport	Diesel-Sulzer	2	13	...	4.0	27.7	25.3
59	*N-7*	Lake Co., Bridgeport	Diesel-Sulzer	2	13	...	4.0	28.0	25.7
	SUBMARINE TENDER:								
2	*Bushnell*	Seattle Con. & D. D. Co.	Pars. trb. gearing	1	14	95.30	98.0	92.7	89.7
	DESTROYER TENDER:								
2	*Melville*	New York S. Co.	Pars. trb. gearing	1	15	95.16	97.63	99 2	99.2
	Transport	Navy Yard, Phila.	Reciprocating	2	14	5.51	9.33	21.0	13.5
	Supply ship	Navy Yard, Boston	Reciprocating	2	14	6.85	9.83	19.9	14.2
	TUGS:								
17	.....	Navy Yard, Charleston	Recip. oil fuel	1	11	...	...	...	...
18	*Pocahontas*	Navy Yard, Norfolk	Recip. oil fuel	1	11	...	...	...	...
	Ferry Launch	Navy Yard, Charleston	Reciprocating	1	...	...	...	...	...

**Wadsworth* delivered July 23, 1915.

COMPLETED SHIPS AND RELATIVE STRENGTH OF THE CONTENDING NAVIES.

Completed ships of the contending navies, August 1st, 1914, including warships of 1,500 tons or more, and torpedo craft of over 50 tons.											Relative strength of the Triple Entente and Dual Alliance.			
Type of vessel.	Great Britain.		France.		Russia.		Germany.		Austria.		Triple Entente.		Dual Alliance.	
	No.	Tons.	No.	Tons.	No.	Tons.	No.	Tons.	No.	Tons.	No.	Tons.	No.	Tons.
Dreadnoughts.....	31	661,650	4	92,368	...	.....	16	351,519	3	60,030	35	754,018	19	411,549
Pre-dreadnoughts....	40	589,385	18	262,675	7	98,750	20	242,800	6	74,613	66	950,810	26	317,413
Coast-defense ships..	.....	.....	1	8,800	2	10,380	2	8,168	6	41,700	3	19,180	8	49,868
Armored cruisers.....	34	406,800	20	201,724	6	63,500	9	94,245	2	13,380	60	672,024	11	107,625
Cruisers.....	74	382,815	9	46,095	9	52,845	41	150,747	5	13,815	92	481,755	46	164,562
Destroyers	167	125,850	84	35,812	91	36,748	130	67,094	18	9,450	342	198,410	148	76,544
Torpedo boats.....	49	11,488	135	13,426	14	2,132	.....	.....	39	6,852	198	27,046	39	6,852
Submarines.....	75	30,362	64	27,940	30	6,506	21	14,140	6	1,686	169	64,408	27	15,826
Total tons comp't'd..	.....	2,208,350	.....	688,840	...	270,861	.....	928,713	...	221,526	.....	3,168,051	.....	1,150,239

—"Scientific American."

OBITUARY.

CHIEF ENGINEER BENJAMIN F. ISHERWOOD.

By REAR ADMIRAL GEORGE W. BAIRD, U. S. N., RETIRED.

Benjamin F. Isherwood was born in New York City on October 6, 1822, and died in that city on June 19, 1915. He was the son of a practicing physician who died at an early age. His mother afterwards married a Civil Engineer.

Mr. Isherwood was graduated at the Albany Academy, in the class with Roscoe Conkling, who was his life-long friend.

He began his career as engineer on the Albany and Schenectady Railroad, with David Matthews, Master Mechanic, after which he was employed in the office of his stepfather on the construction of the Croton Aqueduct for New York City, and later on the Erie Railroad. Mr. Isherwood designed the light-house on Sankaty Head, Nantucket, when a mere youth. He was sent to France by the Treasury Department to superintend the construction of lenses of his own design and to make an examination and report on the light-houses of France.

When the Engineer Corps of the Navy was created, in 1844, Mr. Isherwood, in order to qualify, worked with machine tools in the Novelty Works at New York. He entered the Navy as a First Assistant Engineer and was promoted to be Chief Engineer in 1848.

During the war with Mexico he saw service on board the *Princeton*, the first screw-propeller ship of the Navy, and on board the *Spitfire*, and was in every action in which the ships of the Navy were engaged in the Gulf.

He served at the Pensacola Navy Yard in 1844–5; on board the *General Taylor* in 1847–8; in the Navy Department in 1852–3, when he designed the first feathering paddle-

wheels—for the *Water Witch*—ever used in the Navy. He was Chief Engineer of the *San Jacinto* from 1854 to 1858, on the coast of Africa and in the East Indies. He was on special duty in Washington in 1859–60, during which time he made complete designs for a class of gunboats for the Russian Government.

In 1861 he was appointed Engineer-in-Chief of the U. S. Navy, and when the Bureau of Steam Engineering was created in 1862, he became its first Chief.

When the Civil War began, in 1861, sailing ships were still being built for the Navy. The Steam Navy consisted of six frigates of small power, six sloops of war, nine gunboats, two despatch boats and five side-wheel vessels of low power. Designs for ships and machinery were made in the Navy Department as rapidly as possible and mercantile vessels which appeared at all suitable were purchased and armed. At the termination of the war the Navy had about 600 vessels of all classes in commission. Under these trying conditions, Mr. Isherwood worked from 16 to 20 hours a day. He not only gave the leading dimensions for the engines, but scrutinized every detail drawing as it progressed, making such frequent changes that the draftsmen (Assistant Engineers of the Navy) were rarely able to claim even a detail as their own design. The Engineers of the Navy were at that time selected from the engine builders, for there were neither schools for mechanical engineers nor any but the most elementary literature on the subject. In the matter of designing, as in scientific research, Mr. Isherwood led; though he selected the flower of the corps for his assistants, he led them all. He conducted numerous scientific and original investigations to enable him to solve the previously unsolved problems which confronted the designer. He was the first who had the courage to attack and disprove the vicious theory of Marriott and Gay-Lussac, and though this brought down on him invectives from the leading engineers of Europe and America, he lived to see them turned into encomiums.

It was from the printed results of his researches, which were

soon confirmed by the admirable works of Drs. Tyndal and Mayer, that the advantages of high-pressure, multiple-expansion engines were made apparent and the loss by cylinder condensation diminished. In short, it was from the results of these researches that ships could be built to cross the Atlantic in less than a week.

Mr. Isherwood made a mark upon the times which few have equalled in any branch of science. The Confederate cruiser *Alabama*, a nine-knot boat, had so far depleted the commerce of the North that there was but little of it left. Though we owned and operated many vessels capable of making 12 knots, and some 15 knots, none of them could catch that evasive cruiser. The demand for greater speed was loud, long and potent. Mr. Isherwood then designed machinery for an 18-knot class of vessel. Three vessels of this class were built and all of them attained the designed speed, although some of the best European engineers had declared it impossible. As the vessels had wooden hulls, a speed of 18 knots would, in fact, have been impossible had not the weight of machinery, battery, etc., been so distributed in the vessel as to prevent any straining of the hull.

"M. V. Dwelshanvers-Derry, the eminent Belgian engineer and man of science," says Dr. Thurston, "now perhaps the leading authority in his department," refers to Commodore Isherwood as "*l' eminent ingenieur en chef de la marine des Etats Unis, le plus fecond des experimenteurs de ces quarante dernieres annees.*"

The two volumes of Isherwood's Experimental Researches have been translated into six European languages.

He was the first to show the proper way to test an engine and determine where all the losses lay.

He possessed not only a wonderfully retentive memory, but also the faculty of "statement" which enabled him to make complicated questions clear to the untutored mind.

Mr. Isherwood was the personification of dignity, politeness and affability.

He married Miss Anna Hausine Münster, to whom six children were born.

In 1873 he purchased a house in 36th Street, New York City, and, taking advantage of the exile of the French communists at that time, employed the best artists among them to decorate it. The walls are artistically painted in oil colors and in gold, and all the furniture and fittings match, making it perhaps as artistic, if not as elegant, a residence as may be found in the city.

Chief Engineer Isherwood will ever be revered by all who knew, honored and loved him for himself and the great work he accomplished.

The frontispiece for this number of the JOURNAL is from a photograph which was taken when Mr. Isherwood was seventy years of age.

ALBERT LLOYD HOPKINS.

Albert Lloyd Hopkins was born September 7, 1871, at Glens Falls, New York, the son of Stephen DeForest and Elizabeth G. Hopkins. His early life was passed and his early education was received in that city and in Troy, New York.

In 1888 he entered the famous Rensselaer Polytechnic Institute in the course of civil engineering. In 1892 he was graduated with high honors, and in later years the Director of the Institute said of him: "About ten per cent. of those who apply are admitted to the Institute, about twenty per cent. of those admitted are graduated, and among these, once in a while, we find a Hopkins."

After a few months' work in the summer of 1892 in an architect's office in Chicago, he was appointed to a position in the Bureau of Construction and Repair, Navy Department, Washington, D. C., which position he held for about eighteen months, coming to Newport News in February, 1894, as a member of the staff of Naval Constructor J. J. Woodward, U. S. N., the first Superintending Constructor assigned to duty

at the works of the Newport News Shipbuilding and Dry Dock Company.

In the summer of 1897 Mr. Hopkins was transferred from Naval Constructor Woodward's office and assigned to the Graduate School of Naval Architecture at the U. S. Naval Academy, Annapolis, Maryland, at which place he was an instructor and lecturer on naval architecture and ship construction.

At the outbreak of the Spanish War, in April, 1898, the officers and students of this school joined the Fleet, and Mr. Hopkins was assigned to the Naval Station at Key West, Florida, the nearest station to the blockading fleet operating in Cuban waters. While at Key West Mr. Hopkins was in charge of all the construction and repair work done for the Fleet at that station. He was also active in improving the efficiency of the plant, installing much new equipment and rendering it capable of serving as a repair station for naval purposes.

It was while engaged in the work at Key West that Mr. Hopkins received from the late W. A. Post, then General Superintendent of the shipyard, an offer to return to Newport News and enter the service of the company. Mr. Hopkins accepted and in August, 1898, returned to Newport News as the personal assistant of Mr. Post.

The able constructive work done by Mr. Hopkins in the years following will always be remembered by those associated with him. Gifted with a rarely keen mind, he was quick to grasp the essentials of any situation. His education and training enabled him to choose unerringly the right course to pursue, and his strong will and personality enabled him to carry to its logical conclusion the course so chosen. United with these strong characteristics were an unfailing courtesy and a consideration for others which endeared him to the hearts of all his associates.

When Mr. Post was made General Manager of the company, in 1905, Mr. Hopkins was appointed Assistant General Manager, and in 1911, when Mr. Post succeeded to the Presidency,

on account of the death of Mr. C. B. Orcutt, Mr. Hopkins was made Manager.

Upon the death of Mr. Post, in February, 1912, Mr. Hopkins was elected Vice President and became the chief executive officer of the company, with headquarters in New York.

In this new field Mr. Hopkins fully sustained the high position accorded to his predecessors, and it was quickly and widely recognized that an able executive was directing the affairs of the Shipbuilding Company. In his own profession, and also among the men his profession called him to meet—bankers, lawyers and men of large business affairs—his influence was deep and ever increasing.

His election to the Presidency of the company, in March, 1914, was recognized as a well earned tribute to his ability and his devotion to the interests committed to his care.

Loyal to his friends and associates, loyal to those who trusted their interests to him, loyal always to his own high ideals, well and truly does he deserve the tribute expressed in the following telegram sent by Mr. Huntington to the company.

"Mrs. Huntington and I are distressed beyond expression at the death of Mr. Hopkins. We believe the company and all the employees share our sorrow and will mourn the loss of a splendid officer and a noble man."

To those who knew him best, to his friends and associates of many years, the tidings of the disaster brought a sure message; well they knew that the gentle, kindly courtesy, the ever present, instinctive disposition to serve others before considering himself would unfailingly include him among those who died that others might live.

Mr. Hopkins was a member of the American Society of Civil Engineers, the American Society of Naval Engineers, the Society of Naval Architects and Marine Engineers, and the American Academy of Political and Social Science.

In June, 1906, Mr. Hopkins was married to Miss May Davies, of Chase City, Virginia, who, with their daughter, May Davies Hopkins, survives him.

Mr. Hopkins is also survived by his mother, of Glens Falls,

New York, and his brother, Charles E. Hopkins, of Hudson, New York. Mr. Hopkins' father, Stephen DeForest Hopkins, died at his home in Glens Falls May 1, 1915, only a few hours after his son sailed on the ill-fated voyage.

CHIEF ENGINEER ROBERT CRAWFORD, U. S. N.

Chief Engineer Robert Crawford died at Lansdowne, Pa., on the 8th of April, 1915, of ticdouloureux, from which he had been a sufferer for two years.

He was born in Scotland in 1842, and came to the United States when four years of age.

He was graduated with honor at the High School in Philadelphia, and became a draughtsman in the Baldwin Locomotive Works, where he remained until appointed a Third Assistant Engineer in the Navy, his appointment dating 23d June, 1863.

He served through the remainder of the Civil War, on board the *Chippewa*, *Monitor*, *Pawnee* and *Periwinkle*, in the North Atlantic Squadron, taking part in the battles of Wilmington, Fort Fisher, etc. He was engineer of the famous iron clad *Stonewall*, after she was turned over to the United States at Havana, and he brought her to Washington. He served on board the *Madawaska*, *Swatara*, *Monongahela*, *Kearsarge* and the *Alert*, and was Instructor in Experimental Philosophy, and also in Steam Engineering, at the Naval Academy, for periods aggregating about six years.

He was retired in 1902, unable to longer endure sea duty. He organized the Williamson School of Manual Training, and was professor there for eleven years, after his retirement. He organized the Manual Training and Reform School at Guantapay, Cuba, and, after it was running smoothly, he became Professor in the Academy at Santiago, de las Vegas.

During the war with the Kingdom of Spain Mr. Crawford was detailed as Inspector of Machinery at the Cramps' Ship Yard, at Philadelphia, where he remained until 1912, when he gave up all active employment.

Mr. Crawford possessed a genial personality, was a good after-dinner speaker, a kind father and an indulgent husband. He leaves a widow, two sons and one daughter. He was an active member of St. John's P. E. Church, at Lansdowne. He was, for years, Chief Burgess of Lansdowne; was a member of the Union Athletic Association, a member of the Loyal Legion, the American Society of Naval Engineers and of the Masonic Fraternity. He was active in all patriotic movements.

In politics he was a Republican, but never took a very active part in its activities. He had a never-ending supply of humorous stories, and he was held in high esteem by his shipmates.

Mr. Crawrord was ever a painstaking and conscientious man, faithful to his trust, and inflexible in his fidelity.—G. W. B.

PUBLICATIONS RECEIVED.

FLEETS OF THE WORLD.—Contains a short glossary of Naval terms; comparative tables of the large-caliber guns of the great Fleets of the world; a list of ships lost in the war from August 5, 1914, to April 15, 1915. Over 100 illustrations. Published by J. B. LIPPINCOTT COMPANY, Philadelphia. Cloth, $2.50.

NATIONAL BULLETIN NO. 20.—An index for National Bulletins Nos. 1–20, offering reliable pipe information that is readily accessible. NATIONAL TUBE COMPANY, Pittsburgh, Pa.

ASSOCIATION NOTES.

THE FOLLOWING MEMBERS AND ASSOCIATES have joined the Society since the publication of the last JOURNAL:

MEMBERS.

Baxter, Thomas, Lieutenant, U. S. Navy.
Blasdell, Francis G., Ensign, U. S. Navy, Ret.
Border, Lee S., Assistant Naval Constructor, U. S. Navy.
Burrough, Edmund W., Ensign, U. S. Navy.
Butler, William J., Ensign, U. S. Navy.
Davis, Arthur C., Ensign, U. S. Navy.
Deets, Samuel R., Ensign, U. S. Navy.
Grady, Ronan C., Lieutenant, U. S. Navy.
Haines, Preston B., Lieutenant, U. S. Navy.
Hird, Harry B., Lieutenant, U. S. Navy.
Kemp, Dennis E., Lieutenant, U. S. Navy.
Kessing, Oliver O., Ensign, U. S. Navy.
Kimberly, Victor A., Lieutenant Commander, U. S. Navy.

Laizure, Dallas C., Lieutenant, U. S. Navy.
Lamont, George P., Ensign, U. S. Navy.
Lanphier, Alfred Y., Ensign, U. S. Navy.
Leigh, Richard H., Commander, U. S. Navy.
McWhorter, Ernest D., Lieutenant, U. S. Navy.
Mallison, William T., Lieutenant, U. S. Navy.
Mann, Joseph R., Jr., Lieutenant, U. S. Navy.
Molten, Robert P., Lieutenant, U. S. Navy.
Nimitz, Otto, Ensign, U. S. Navy.
Oates, Eugene T., Ensign, U. S. Navy.
O'Brien, William H., Jr., Lieutenant, U. S. Navy.
Oman, Joseph W., Captain, U. S. Navy.
Parsons, Henry E., Lieutenant, U. S. Navy.
Quinlan, Earl H., Ensign, U. S. Navy.
Wagner, Frank D., Ensign, U. S. Navy.
Walker, Myron J., Ensign, U. S. Navy.
Welden, Fred, Lieutenant, U. S. Navy.
Withers, Noble, Ensign, U. S. Navy.
Wright, Carrol Q., Jr., Ensign, U. S. Navy.

ASSOCIATES.

Jones, Russell C., Griscom-Russell Co., 90 West St., New York City.

MacFadden, Carl K., Room 1208, 90 West St., New York City.